MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXXVI, PART 1.

THE GEOLOGY OF SPITI, WITH PARTS OF BASHAHR AND RUPSHU. *By* H. H. HAYDEN, B.A., B.E., F.G.S., *Deputy Superintendent, Geological Survey of India.*

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOLUME XXXVI, PART 1.

THE GEOLOGY OF SPITI, WITH PARTS OF BASHAHR AND RUPSHU. *By* H. H. HAYDEN, B.A., B.E., F.G.S., *Deputy Superintendent Geological Survey of India.*

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INTRODUCTION.

Our knowledge of the geology of that part of the higher Himálayan ranges which lies to the west of the Nepál frontier has been derived chiefly from the examination of three distinct areas, namely, the Kumaon and Garhwál Himálayas on the east, Kashmir with Ladákh on the west, and Spiti, lying between these two. This threefold partitioning is not due to any geological or stratigraphical peculiarities of the respective subdivisions, but merely to their physical conformation, each area being accessible from one or more routes which are more or less central to it, but do not give access to the others, while the passage from the central area, Spiti, to those lying on either side is a matter involving considerable time and difficulty. The inevitable consequence of these conditions is a lack of homogeneity in the geological results, a lack still further enhanced by the fact that, except with regard to the lower trias, no two areas had until quite recently been examined in any detail, nor, with a few exceptions, even visited, by one and the same observer.

Naturally, it is to the central, or Spiti, area that we look for the means of correlating what knowledge we have of the neighbouring divisions; but this is a matter of no small difficulty. The eastern

area, indeed, has been described in considerable detail, first by General Strachey,[1] the pioneer of Himálayan stratigraphical geology, and subsequently by Mr. Griesbach;[2] again in 1891, parts of the same area were visited by Messrs. Griesbach and Middlemiss, accompanied by Professor Diener, whose researches[3] have added largely to our knowledge of the characters and correlation of the Himálayan trias. Still further additions have been made during the last few years by the work of Messrs. La Touche and Smith and Drs. Noetling, Walker and von Krafft. So far, then, as this area is concerned, we have a considerable amount of material available for our purpose. Unfortunately the same cannot be said of the western, or Kashmir, area. Practically the whole knowledge that we possess is derived from Mr. Lydekker's work on the geology of Kashmir.[4] The detailed study of so large an area would necessarily involve many years' labour, and Mr. Lydekker found it impracticable to attempt any minute subdivision of the sedimentary rocks. He, therefore, divided the whole stratigraphical series into three systems, the tertiary, the Zánskár, and the Panjál, in the last of which he included the cambrian and silurian systems, while the Zánskár represents all European systems from the base of the carboniferous to the top of the cretaceous. In each of the two latter systems he recognised certain subdivisions corresponding to the various series of Spiti, as described under local names by Stoliczka. It is thus possible to make some attempt to correlate roughly these two adjoining areas, but the general absence of detailed descriptions of sections or of fossiliferous horizons renders any accurate correlation impossible, nor can this be attempted until the stratigraphy of Kashmir has been studied in greater detail.

The fact that a portion of Spiti was visited by Mr. Griesbach on the completion of his work in the Kumaon and Garhwál Himálayas,

[1] Quart. Journ. Geol. Soc., VII (1851), p. 292.
[2] Memoirs, G. S. I., vol. XXIII.
[3] Denkschrift. d. k. Akad. d. Wiss., Wien, 1895.
[4] Memoirs, G. S. I., vol. XXII.

and his account of the geology of that part traversed by him,[1] render a correlation of the central with the eastern area a comparatively simple matter, and one which has been still further facilitated by the numerous detailed sections to be found in his memoir, as well as by his employment of European nomenclature in his description of the corresponding rock-systems of the Himálayas.

Nomenclature.

In rapid or preliminary traverses of a previously unexplored area where, owing to paucity of fossils or to other causes, the various sedimentary formations cannot be definitely referred to known European equivalents, the adoption of local names for the more prominent lithological units is no doubt advisable and even necessary, but when the survey has advanced to a further stage, and sufficient palæontological evidence can be adduced to determine the approximate homotaxial relations of the more important subdivisions, the multiplication of terms leads merely to confusion. In the present memoir this has been kept in view, and the various systems have, so far as possible, been designated by the names of their European equivalents; a few terms, however, such as "Spiti Shales," and "Giumal Sandstone," which have now become historical and have been universally applied throughout the Himálayas, have been retained; while others, such as "Párá limestone," which have no special appropriateness, and may even include portions of two different systems, have been discarded. This applies especially to Mr. Lydekker's terms "Zánskár" and "Panjál," under each of which names he included, as already stated, more than one European system, and where parts of the area surveyed by him have been touched on in the following pages, his terminology has not been employed.

Maps.

The geological map accompanying the present memoir is the joint work of the late Dr. von Krafft and the present writer, and is based on the "Atlas of

[1] Memoirs, G. S. I., vol. XXIII, pp. 206–223; Records, G. S. I., vol. XXII, pp. 158–167.

India" (1 inch = 4 miles). All boundaries were carefully followed as far as possible, but, owing to the small scale and inaccuracies of the topographical map, it has frequently been found impossible to reproduce the smaller structural details. In addition to this, owing both to physical and political difficulties, certain parts of the range separating Spiti from Western Tibet were inaccessible, and geological boundaries could therefore be drawn only approximately. This is especially the case in that part of To-tzo (Western Tibet) which lies to the east of the Spiti river, and which could be only rapidly and surreptitiously traversed; for the local inhabitants, although as a rule exceedingly friendly and not disposed to place any serious obstacles in the way of travellers, have during the last few years jealously guarded their frontier, in consequence of a recent attempt on the part of a tactless and irresponsible traveller to force his way in the teeth of all opposition into the more easterly parts of their country.

CHAPTER I.

PREVIOUS ACCOUNTS OF THE GEOLOGY OF SPITI.

Although Spiti had been visited by geologists at various times during the past century, no detailed systematic survey had been made, and in 1898 it was decided that a more careful study of the whole area should be undertaken. For this purpose the present writer was deputed to Spiti in the summer of that year; the work was continued by him, accompanied by the late Dr. von Krafft, in 1899, and by the present writer again during the summer of 1901.

The work carried out during the above three seasons, while claiming no pretensions to detail, has, however, been brought up as far as possible to an uniform degree of completeness, sufficient, it is hoped, should occasion ever arise, to facilitate an intimate study of horizons and sections.

Of the various papers relating to Spiti and neighbouring areas the following are of chief importance:—

STOLICZKA (*F.*).—Geological sections across the Himálayan Mountains.
(Memoirs, G. S. I., vol. V (1866), art. i, pp. 1—154.)

STOLICZKA (*F.*).—Summary of geological observations during a visit to the provinces—Rupshu, Karnág, South Ladákh, Suroo and Drás—of Western Tibet, 1865.
(Memoirs, G. S. I., vol. V (1866), p. 337.)

MALLET (*F. R.*).—On the Gypsum of Lower Spiti.
(Memoirs, G. S. I., vol. V (1866), art. ii, pp. 153—172.)

MCMAHON (*GEN. C. A.*).—Notes of a tour through Hangrang and Spiti.
(Records, G. S. I., vol. XII, pp. 57—69.)

OLDHAM (*R. D.*).—Notes on the Geology of the North-West Himálayas.
(Records, G. S. I., vol. XXI, pp. 130—143, and pp. 149—159.)

LYDEKKER (*R.*).—Geology of Kashmir.
(Memoirs, G. S I., vol. XXII.)

GRIESBACH (*C. L.*).—Geological notes.
(Records, G. S. I., vol. XXII, pp. 158—167.)

GRIESBACH (*C. L.*).—Geology of the Central Himálayas.
(Memoirs, G. S. I., vol. XXIII.)

In addition to the above, progress reports by the late Dr. von Krafft and by the present writer were published, during the course of the work, in the General Reports, Geological Survey of India, for the years 1898-1899, 1899-1900, 1901-1902.

McMAHON; OLDHAM.

Of the above papers, those of McMahon and Oldham relate chiefly to the vexed question of the correlation of the beds of Spiti with the pre-tertiary formations of the outer Himálayas ; these will be discussed below (*vide* chap. VIII).

MALLET.

The paper by Mallet is confined chiefly to mineralogical questions, including that of the origin of the gypsum,[1] and does not deal with stratigraphy.

STOLICZKA.

Of the remaining papers, those of Stoliczka embody the first systematic account of the geology of Spiti. Although, owing to the short duration of his visit, this account necessarily lacks completeness and detail, yet the majority of his general conclusions have been borne out by the recent, more detailed work.

He divided the whole stratigraphical sequence into the following ten series :—

Chikkim beds	. Cretaceous.
Giumal sandstone	. Upper oolite.
Spiti shales	. Middle oolite.
Upper Tagling limestone	. Middle lias.
Lower „ „	. Lower „

[1] *Vide infra*, p. 101.

Párá limestone	. Rhætic.
Lilang series	. Upper trias.
Kuling series	. Carboniferous.
Muth series	. Upper silurian.
Bhabeh series	. Lower „

Each of the above series will be dealt with in detail in the chapters relating to the systems that they represent.

GRIESBACH.

Mr. Griesbach's chief object in visiting Spiti was to endeavour to remove certain discrepancies existing between Stoliczka's account of the stratigraphy of Spiti and the conditions observed by him in the Kumaon and Garhwál Himálayas. His short account, although based on a somewhat rapid traverse, constitutes a distinct advance in our knowledge of the geology of Spiti.

As will be seen from his memoir, the chief points on which he differed from Stoliczka, were—

(1) the age of the Muth quartzite (8)[1] and underlying beds;

(2) the vertical extent of the carboniferous system;

(3) the age of Stoliczka's "Kuling series";

(4) the presence or absence of beds of lower triassic age.

With regard to the first point, subsequent work has shown that Stoliczka was correct in regarding the beds underlying the Muth quartzite as of silurian age but no direct evidence as to the age of the quartzite itself has yet been found.

With regard to the carboniferous system, Mr. Griesbach has shown that Stoliczka had erroneously included in it the "Productus shales," now known to be of permian age: these Stoliczka named the "Kuling shales," and included with them certain dark limestones found at Kuling and at Muth, and which are, in part at least, of carboniferous age.

Mr. Griesbach was also the first to prove the existence of the lower trias in Spiti, Stoliczka having failed to notice it, though it appears that he subsequently came to the conclusion that beds of that age were to be found in the Himálayas.[2]

[1] This is the number employed by Mr. Griesbach in his list of formations.

[2] Memoirs, G. S. I., vol. V, p. 345.

CHAPTER II.

CAMBRIAN SYSTEM

A glance at the map will show that the Spiti valley has a general N.-W.—S.-E. trend, to which the strike of the sedimentary rocks to a great extent conforms. With this strike is combined a northerly dip: hence the outcrops of the various systems form a series of bands, the oldest lying to the south.

The most southerly band constitutes a part of the oldest known sedimentary system in the Western Himálayas, and to a large extent forms the great snowy range separating Spiti from Kulu and Bashahr. It has been designated by a variety of names, the best known of which are "Azoic" (Strachey), "Bhabeh series" (Stoliczka) and "Haimanta" (Griesbach).

Metamorphic rocks. Gneiss.

Before passing on to a description of this system, as seen in Spiti, it is necessary to notice certain beds which are said to underlie it in other parts of the Himálayas. These are Mr. Griesbach's "vaikrita" system, and the so-called "central gneiss." The latter rock has been found by General McMahon to be in reality a gneissose granite: it is seen throughout the Sutlej valley from Wangtu to Shipki, and again along the Spiti river, and at Changrizang on the lower Párá river, one of Stoliczka's type-localities, where it is found intrusive both in cambrian and permian beds.

Schists of Wangar valley;

The other series described by Mr. Griesbach from the Niti area, as of probably pre-cambrian age, is the vaikrita system, composed of schists, talcose rocks, phyllites and gneiss. From near Wangtu bridge on the Sutlej to within a short distance of the Bhabeh Pass, the road passes over a complex series of mica-gneisses, kyanite-schists and garnetiferous mica-schists, with basic igneous rocks and much intrusive granite (central gneiss). The

schists might possibly be regarded as the equivalents of Mr. Griesbach's vaikrita system. Similar schists are, however, found in the Sutlej valley between Spueh and Hango, and again on the left side of the Spiti river below Chango. In the latter localities the kyanite-schists and garnetiferous mica-schists are found to pass horizontally into less altered phyllites and clay-slates belonging to the cambrian system and corresponding to Mr. Griesbach's middle haimantas. Similarly, highly altered staurolite and kyanite schists are found between Asrang and Pangi, where the intrusive biotite granite is found in contact with the cambrian slates. There is therefore no reason to suppose that the schists of the Wangar valley represent the vaikrita system, for they also are probably only altered representatives of the cambrian slates, while the more acid gneisses, which occur among them, may very possibly have been produced by the alteration of the fine grits and quartzites of the same system.[1]

of the Sutlej valley.

"Haimanta" system of Griesbach.

The haimanta system has been subdivided by Mr. Griesbach into three groups—

(*c*) *upper haimanta*—consisting of "quartz shales and slates" (= "red quartz shales");

(*b*) *middle haimanta*—"shales and silky phyllites, with great thickness of quartzites";

(*a*) *lower haimanta*—"quartzite, generally purple, with great thickness of conglomerate."[2]

Of the above subdivisions, the upper and middle can be readily recognised in all the older palæozoic sections in Spiti and Bashahr, but the lowest, characterised by the presence of conglomerates, has not been found. Mr. Griesbach states,[3] however, that he found a "conglomerate, or rather, boulder-bed" among the haimantas of Spiti. In spite of

[1] It is probable that not only in this area, but also in other parts of the Himálayas, many of the rocks which have hitherto been relegated to the limbo of the "crystalline schists" are in reality merely altered sedimentary beds.

[2] Memoirs, G. S. I, vol. XXIII, p. 51.

[3] *Ibidem*, p. 210.

careful search, neither the late Dr. von Krafft nor the present writer succeeded in finding this among the lowest beds, but a conglomerate, very similar to that described by Mr. Griesbach, was found overlying the cambrian beds, and invariably defining the boundary between them and the silurian rocks. Numerous blocks of the conglomerate are found along the route traversed by Mr. Griesbach, and since he states[1] that he did not examine the beds in any detail, it is possible that on meeting with a rock bearing so close a resemblance to the lower haimanta conglomerate of Niti, he came to the natural conclusion that it was the same. A fuller description of this rock will be found below (see p. 22).

Oldest sedimentary rocks of Spiti.

The oldest sedimentary rocks, therefore, with which we have to deal are the slates and quartzites belonging to Mr. Griesbach's middle haimantas. They consist chiefly of soft, ferruginous clay slates,—thinly foliated and often crushed and micaceous (phyllite)—interbedded with bands of grey and purple quartzite. Thin beds of grit ranging from a few inches to a foot in thickness are not uncommon, especially near the upper boundary of the series. These rocks extend from the north-western end of Spiti, throughout the whole length of the chain of snowy peaks separating Spiti from Kulu and the Wangar valley, into the valleys of the Teti (Taite) and Thanam rivers in Bashahr, continuing eastwards from Sungnam, and forming most of the hills on either side of the Sutlej and Spiti rivers below Lio and Chango in Kanaur. At either end, they appear to run on in the direction of Garhwál and Kumaon on the south-east and of Lahaul on the north-west, and extend for many miles down the valley of the Sutlej, below its confluence with the Spiti river. Along their southern boundary they are found, in Spiti and Bashahr, in contact with great masses of intrusive granite. Near the line of junction, they have been highly altered, chiefly into garnetiferous mica schist, biotite schist, biotite-kyanite schist and biotite-staurolite schist.

Altered by contact-metamorphism.

[1] *Op. cit.*, p. 120.

In the valley of the Chandra river, between Kulu and Spiti, the commonest product of alteration is a dark biotite schist, composed of biotite, quartz, felspar (orthoclase, albite and microperthite), with some rutile and zircon.

Biotite schist.

In the valley of the Sutlej, the products of contact-metamorphism are similar to those in the Chandra valley, but to the other component minerals are added kyanite and staurolite, the former occurring in large crystals, often of a beautiful blue colour, which has led to their being mistaken for sapphires. Fine specimens of this biotite-kyanite schist are found between Naku and Chango on the left side of the lower Spiti river, and also on the left side of the Kozhang river on the old road from Pangi to Asrang. At the latter locality, staurolite occurs in great quantity, locally replacing most of the kyanite, the rock thus becoming a biotite-staurolite-kyanite schist: it contains also quartz, orthoclase, albite, zircon and large quantities of rutile; an iron ore, probably ilmenite, is found in small grains scattered through the staurolite, to which it appears to be entirely confined.

Biotite-kyanite schist and biotite-staurolite schist.

In the neighbourhood of Lio, in the valley of the Lipak river, the effects both of contact- and of dynamo-metamorphism are very pronounced, and on the right bank of the river, at about two miles above its junction with the Sutlej, the lower slates and quartzites contain the only rock, which, having regard to its appearance and position, could be supposed to belong to Mr. Griesbach's lower haimanta conglomerates. The rock is a conglomerate forming a bed of varying thickness, and composed of more or less rounded and lenticular fragments of white quartz, scattered through a matrix of fine-grained biotite schist. The band is usually ten or twelve feet in thickness, and in places contains the white pebbles throughout its whole extent; in other places, however, only narrow strings of pebbles, separated by bands of schist, run both parallel and obliquely to the original direction of stratification of the rock. When first seen in the bed of the river, the conglomerate was taken for the one which occurs throughout Spiti at the base of the silurian system

Autoclastic conglomerate of Lipak river.

subsequent examination showed, however, that it did not immediately underlie that system, from which it is separated by a great fault, but occurred low down among the middle haimanta slates and quartzites, and when followed for a short distance, it was found to pass gradually into a great mass of white quartz, which occurs at the water's edge on the right bank of the river. An examination of this exposure at once showed that the rock was an autoclastic conglomerate, formed by the crushing of veins and narrow strings of quartz, which are seen running out from the main mass: these become broken up into fragments and eventually take the form of strings of pebbles, sometimes coalescing again into veins, at others forming bands of pseudo-conglomerate. Further evidence as to the true character of the rock was found on the opposite side of the stream, where an old basic dyke is seen, part of which has been similarly converted into an autoclastic conglomerate.

Age of the slates and quartzites.

No fossils have been found in Spiti or in Bashahr, in this series of slates, quartzites and grits, and there is, therefore, no direct evidence as to its age. By Stoliczka it was included in, and constituted the greater part of, his "Bhabeh series," which he classed as "lower silurian." There can be little doubt that, in common with most continental and many English geologists of his time,[1] he employed the term "silurian" in its widest sense, to include all pre-devonian fossiliferous systems then known. His "lower silurian" would therefore include the cambrian system, and his "upper silurian" the silurian system of modern English geologists.[2]

The "Bhabeh series" was subsequently identified by Mr. Griesbach with his haimanta system, which he regarded as of cambrian, and probably also in part of pre-cambrian, age.

[1] And also some prominent continental geologists of the present day; *see* de Lapparent, *Traité de Géologie*, 4th edition.

[2] In the present memoir the cambrian is retained, in conformity with modern English usage, as a separate *system*. In the silurian are included all the beds between the cambrian and devonian systems, *i.e.*, the "ordovician" and "silurian" (lower and upper silurian), respectively.

Thickness.

The total thickness of the series cannot be even approximately determined, for although extending for many miles in the valleys of the Thanam, Pin and Parahio rivers, with a more or less constant northerly dip, the beds have undergone repeated folding, and their apparent thickness is thus very great, especially in the Pin and Thanam valleys, where the arches of the anticlines have been completely removed by denudation. In the Parahio valley, however, remains of numerous folds can still be seen (see Pl. I, fig. 2), thus proving that the enormous thickness is only apparent; it is probable, however, that an estimate of between two and three thousand feet will not err on the side of excess.

Red and black slates.

The overlying beds which presumably comprise Mr. Griesbach's upper haimantas, consist of a series of black, purple and grey slates, with grey, green, and red quartzites. The lower part of the series is chiefly argillaceous, and the upper mainly siliceous. The grey and purple slates are highly ferruginous, and contain large quantities of hæmatite and limonite, pseudomorphous after pyrite; the weathered surfaces of the rock are consequently completely coated with orange and bright red films of ochre, and the outcrop stands out as a brilliant red band running through the darker slates, and presumably constituting Mr. Griesbach's horizon of "red quartz shales." Among the argillaceous beds are bands of an intensely black, carbonaceous shale, resembling the carbonaceous shales of Simla.

The red and black beds form an unmistakable and very constant horizon, well seen in the Parahio and upper Pin valleys of Spiti and the Thanam (locally called Samandar) river in Bashahr, where it has a thickness of not less than 1,000 feet.

Trilobite beds.

In the Parahio valley the upper siliceous beds pass up gradually into a series of grey and green micaceous quartzites and thinly foliated slates and shales, with narrow bands of light-grey dolomite.

The slates, which are usually dark-blue or black, vary in composition

from a soft, argillaceous rock to a hard, siliceous variety with much mica. They are very finely laminated and much crushed, and the direction of foliation being usually oblique to the bedding, the rock frequently resembles a needle shale. The slates are interbedded with great regularity with grey, yellow or whitish quartzites, which are almost invariably capped by a narrow band of either calcareous quartzite or dolomitic limestone only a few inches in thickness. The limestone, which is grey on fresh fracture, weathers to a pinkish or brownish red, and is again overlain by slates, which are at first argillaceous but gradually become more and more siliceous, till they pass up again into quartzites; this alternation continues with great regularity for many hundred feet. Towards the top of the series the argillaceous beds give place to light-coloured siliceous slates and thin-bedded, flaggy quartzites with bands of red and pink dolomite, which latter gradually increases in frequency and thickness, till it becomes the predominant rock.

Dolomite.

These beds constitute the oldest fossiliferous series hitherto found in Spiti. The fossils, which consist chiefly of *Lingulella* and trilobites, are most numerous in the argillaceous beds, but the narrow bands of limestone, and, in places, the flaggy quartzites, are also fossiliferous.

The most complete section is seen in the valley of the Parahio, where the following sequence of rocks forms the steep hills on the left bank of the river, above Maopo E. G.[1]:—

19. Conglomerate.		
18. Quartzite and siliceous shale . . .	about	50 feet.
17. Grey dolomite, weathering brownish-red .	„	20 „
16. Flaggy sandstone, quartzite and siliceous slate	„	40 „
15. Grey dolomite, weathering brownish-red .	„	30 „
14. Siliceous slates, with grey quartzite bands and thin beds of pink dolomite (slates chiefly grey and green, but weather pink).	„	250 „
13. Dark siliceous slates, with a few fragmentary trilobites	„	10 „
Carried over .		400 feet.

[1] E. G.=Encamping ground.

	Brought forward about	**400**	**feet.**
12. Siliceous slates and flaggy quartzite . .	„	30	„
11. Siliceous and argillaceous slates, with trilobites	„	6	„
10. Grey slaty quartzite, capped by dolomite (6″)	„	50	„
9. Slates, siliceous above and argillaceous below, with trilobites.	„	30	„
8. Dark-grey quartzite	„	60	„
7. Pink shaly dolomitic limestone, with trilobites	„	12	„
6. Calcareous quartzite, with *Lingulella* and trilobites, underlain by narrow band of fossiliferous limestone (2″) and argillaceous slates, with many trilobites . . .	„	10	„
5. Grey micaceous quartzite, with thin bands (¼″ to 2″) of mica schist	„	150	„
4. Slates, alternating with narrow bands (⅛″ to 4″) of grey limestone, with *Lingulella* and trilobites	„	10	„
3. Slate, chiefly siliceous, and quartzite . .	„	150	„
2. Dark slate, with trilobites	„	30	„
1. Red and green slaty quartzites, with *Lingulella* and trilobites in the uppermost bands .	„	250	„
		1,188	feet.

The thickness of the individual sub-divisions as given in the above list is in most cases merely approximate, for the whole series is disturbed by faults and no really consecutive section can be found.

Fossiliferous horizons.

The lowest horizon at which fossils were found occurs near the top of the reddish quartzites (No. 1), which overlie the bright red slate series. The rock from which they were obtained is a hard, calcareous and micaceous quartzite, containing numerous valves of a small brachiopod resembling *Lingulella*; with these are associated fragments of the head-shields of a trilobite, too badly preserved, however, for even generic determination. Above this are flaggy quartzites, in thin beds, the surfaces of which are covered with impressions resembling those ascribed by Nathorst to the tracks of invertebrate animals.[1] The same markings are common in, and characteristic of, these quartzites throughout Spiti.

[1] Kong. Svensk. Vet. Akad. Handlingar; Bd. XVIII, Bd. XXI.

The next horizon from which fossils have been obtained in any appreciable number is bed No. 2 ("dark slate with trilobites"). In this bed and in No. 4, numerous remains (chiefly head-shields) of trilobites occur; they are unfortunately all poorly preserved.

Bed No. 6 has yielded a large number of specimens, many of which are in a very fair state of preservation; they consist chiefly of species of *Ptychoparia*, Corda and allied genera.

In bed No. 9, *Ptychoparia* is still found, and with it large numbers of fragments of *Olenus* sp., and *Dikelocephalus* sp.

The highest zone in which determinable fossils have been found is bed No. 13: they are, however, not numerous. *Ptychoparia* is very rare, being almost entirely replaced by species of *Olenus*.

Collections were made from all the above horizons, but have been sent to England for description. It is therefore at present only possible to give the above generic determinations, founded on a cursory examination made by the present writer before the despatch of the materials to England. These data, though meagre, are yet sufficient to warrant the inference that the fossiliferous beds are of upper—possibly also of middle—cambrian age.

As already stated, the series attains its greatest development in the valley of the Parahio, where its total thickness is nearly 1,200 feet. In the section described, the uppermost dolomite has undergone considerable alteration and contains no determinable fossils, though a few fragments of head-shields of trilobites have been found in it, but the lithological continuity of the series up to the base of the conglomerate (19) renders it desirable, in the absence of proof to the contrary, to place the whole in one and the same system. In addition to this, a distinct change in the character of the deposits, accompanied by a marked unconformity, occurs at the base of the conglomerate, and in view of the not infrequent coincidence of a palæontological with a lithological break, the upper quartzites, slates and dolomites have been included with the underlying fossiliferous beds, in the upper

Unconformity above the trilobite beds.

cambrian, and the overlying conglomerate adopted as the base of the silurian system.

This lithological break, with the accompanying unconformity, is constant throughout Spiti and Bashahr. The section above described is the most complete yet found, and the unconformity between the shales and quartzites (bed 18) and the overlying conglomerate (bed 19), although distinct, is not pronounced, but a few miles further to the south, on the right side of the Parahio and in the high range between that river and the Pin valley, as also in the Thanam river in Bashahr, ample evidence of the break exists; the conglomerate is found resting on a denuded surface of the cambrian rocks, the greater part of the fossiliferous beds having in some instances been removed prior to its deposition.

To the west and north the upper cambrian system is found chiefly in the great snowy range separating Spiti from the Kulu valley, and is to a large extent inaccessible, but wherever seen, similar denudation of the older rocks is found to have taken place before the deposition of the conglomerate.

Evidences of local disturbance during upper cambrian times.

Even before the close of the cambrian period local disturbance appears to have set in. Evidence of this is found on the right bank of the Parahio, above Changnu E. G., where the trilobite-bearing slates are overlain by the following series of beds:—

19. Conglomerate.

Unconformity.

18. Dark siliceous and carbonaceous slates.
17. Dolomitic limestone, passing horizontally into coarse conglomerate.
16. Red siliceous shale.
15. Dolomitic limestone.
14. { Pink and red limestone. / Grey limestone with shell remains.

It will be seen that this section, which occurs at about a mile to the south-east of the river, corresponds to the section already described from the left bank, but between these two localities a striking change occurs in the upper limestone (No. 17) which passes horizontally into a great mass of coarse conglomerate, composed of large blocks of the

same limestone in a calcareous matrix. Mixed with the limestone blocks are a few pebbles and angular fragments of quartzite, resembling that of the underlying beds. The conglomerate occurs on both sides of the river, but is particularly well seen above the right bank, where it forms a cliff above 250 feet in height, but rapidly dwindles away on either side and passes horizontally into the normal dolomite.

The main mass of the conglomerate consists of very large blocks, often as much as a ton in weight, of the grey limestone and of the dolomite found in the adjacent sections, but near the base of the cliff it is composed of large boulders—many being of quartzite—from six inches to a foot in diameter, embedded in a siliceous and slaty matrix. This rests on an eroded surface of upper cambrian slates and quartzites (Pl. VI). It would appear, therefore, that towards the close of the cambrian period disturbances had begun to take place locally, resulting in contemporaneous erosion. The original conditions, however, seem to have been soon restored, for both the conglomerate and the dolomite are overlain by the same band of dark slates (No. 18), above which occurs the great cambro-silurian unconformity, which extends throughout Spiti and Bashahr.

Cambro-silurian unconformity.

No further evidence of local disturbance during upper cambrian times has been observed, for the highest beds of that system have been found only in the Parahio valley. Thus, on the high range to the west of Muth in the Pin valley and a few miles south-east of the Parahio, the lower silurian conglomerate rests in places on a small thickness of the lower dolomite (bed 15), and in places on the underlying slates, while on the lower spurs on either side of the Pin river, the dolomite has completely disappeared and only the lower beds of the upper and middle cambrian are found. Higher up the river also, near Baldar, the upper beds are entirely absent.

Still further to the east, in the valley of the Thanam river, near the junction of that river with the Chokdinjan Chu, the greater part of the upper and middle cambrian series has been removed. No trace is seen of the dolomite, the conglomerate being underlain by

about 150 feet of shale and slate resting upon the basal quartzites (No. 1). These in turn pass down into the red, ferruginous and carbonaceous series.

Further east, again, in the lower Thanam valley, the trilobite beds appear to be entirely absent, and on the southern side of the Hang-rang Pass the silurian rocks lie upon the red and carbonaceous slates. Here, however, and indeed throughout Bashahr, the rocks are greatly disturbed, and the junctions frequently confused by faults: this is especially noticeable in the hills on the right side of the Sutlej and lower Spiti rivers, between Sungnam and Lio, where faults and granite intrusions are numerous, and the older palæozoic beds both altered and disturbed.

It has been seen, therefore, that the pre-silurian rocks of Spiti fall into three main subdivisions—

Subdivisions of pre-silurian beds of Spiti.

(*c*) an upper, fossiliferous series of slates, quartzites and dolomites, only the lowest beds of which have been found in the areas examined by previous observers: thickness—about 1,200 feet;

(*b*) a middle subdivision, consisting of bright red and black (ferruginous and carbonaceous) slates, with some quartzites; this is well developed in the Pin, Parahio and Thanam valleys, and presumably corresponds to Mr. Griesbach's upper haimantas: thickness—about 1,000 feet;

(*a*) a series of dark slates and quartzites, corresponding to Mr. Griesbach's middle haimantas: thickness—between 2,000 and 3,000 feet.

The age of the highest member (*c*) is undoubtedly upper, and possibly in part middle, cambrian, and considering the relative thickness of this and the lower subdivisions, and comparing these with the thickness of the cambrian system in other parts of the world, it would seem quite justifiable to include the whole sequence, which is a perfectly continuous one, in the cambrian system, and thus dispense in Spiti with the provisional terms "Bhabeh series," originally proposed by Stoliczka, and "Haimanta," subsequently adopted by Griesbach.

CHAPTER III.

SILURIAN SYSTEM.

Throughout Spiti the cambrian beds are overlain by a great system of shallow-water deposits, broadly consisting of conglomerates at the base, followed by grits, and passing up gradually into a thick mass of gritty quartzite, with occasional thin bands of shale.

Lower silurian conglomerate and quartzite.

The age of these rocks has hitherto been regarded as upper silurian. By Stoliczka it was included in his Muth series, of which it formed the lowest member; that series he regarded as of "upper silurian" age, but it has already been stated that he most probably included the cambrian in his silurian system, and his "upper silurian" would therefore include the whole silurian system of the present memoir.

By Mr. Griesbach the quartzite was regarded as of upper silurian age and identified by him with a similar formation found in Kumaon and Garhwál.

In Spiti, internal evidence of the age of the series is entirely wanting, for no fossils have been found in it anywhere, but it overlies—though unconformably—upper cambrian beds, and underlies a series of quartzite, shale and limestone, the lowest beds of which are almost certainly not younger than Caradoc.

The lower silurian system of Spiti has been described by Mr. Griesbach as consisting of "thin-bedded, coral limestone of dark grey colour, with occasional intercalations of siliceous and shaly beds of greenish and pink colour. Near its junction with the red quartz shales, beds of dark (fossiliferous) coral limestone alternate with the red shales, which are often replaced by greenish-grey beds of otherwise similar lithological character."[1] The thickness of this series he states to be about 300 feet.

[1] Memoirs, G. S. I., vol. XXIII, p. 218.

In spite of repeated and careful search, no trace of this limestone was found below the red silurian quartzite in normal sections either by the late Dr. von Krafft or by the present writer. The section on which Mr. Griesbach's description was based is presumably that near Muth, where the beds have been somewhat disturbed, and without the assistance of the sections seen on the opposite side of the Pin river and in other parts of Spiti the true sequence might be somewhat difficult to determine.

The following may be taken as a type of the sequence of beds between the cambrian (upper) quartzites and the silurian quartzite:—

Lower Silurian.	*g.* Red, gritty quartzite, about	1,500 feet.
	f. Grit and quartzite, passing down into coarse conglomerate, which alternates with quartzite	100 „
	e. Conglomerate, composed of fragments of white quartz (often angular) in fine-grained slaty matrix	2 „
	d. Coarse, reddish and purple conglomerate	73 „
Cambrian	*c.* Purple quartzite, with slate	50 „
	b. Micaceous quartzite, passing down into greenish slates	22 „
	a. Purple quartzite, and slate.	

This section is seen near Shián, in the Pin valley, a few miles south of the village of Muth.

The slates (*c*) contain fragments of trilobites resembling those found in the lowest beds of the fossiliferous series of the Parahio valley.

The above series represents the alternating beds of "conglomerate and sandstone" described by Stoliczka as underlying the lowest subdivision ("purple rocks") of his "Muth series." Beds (*c*) and (*d*) are separated here by a fault (Pl. VIII) which continues across the Pin valley and is seen again near Muth: it does not, however, affect the section to any appreciable extent, for the sequence is almost identical with that seen in the unfaulted sections high up among the hills to the west-south-west of Muth.

On account of the unconformity which has been shown to exist between the upper cambrian beds with trilobites and the conglomerates, it has been, for reasons stated in the last chapter, considered advisable to adopt the latter as the basal bed of the silurian system. As might

be expected, the conglomerate series is itself somewhat variable, both in character and thickness. This will be seen most readily from a description of a few of the more important sections. That at Shián has already been described; but others are seen in the high range to the south-west of Muth, near Baldar, in the upper Pin valley, in the valley of the Parahio and in the Thanam valley in Bashahr. Numerous other exposures occur, chiefly near the heads of the rivers flowing into the Spiti river from the south-west, but those enumerated above will be sufficient to indicate the salient characters of the series.

Conglomerate in Pin valley.

In the Parahio valley, the two sections, from which the cambrian rocks have been described, also afford typical exposures of the lower silurian beds. In the hills on the right bank of the river, the sequence is as follows (in descending order):—

In Parahio valley.

4.	Pinkish-red quartzite, passing down into reddish grit	about	1,500 feet.
3.	Conglomerate, composed of large pebbles of quartzite and quartz, in a fine, gritty matrix .	„	50 „
2.	Hard, gritty sandstones, with pale yellowish-grey and white quartzite	„	20 „
1.	Conglomerate, composed of pebbles of quartzite, with some larger boulders of upper cambrian dolomite	„	30 „

The two bands of conglomerate differ slightly from one another, for the lower bed contains, in addition to pebbles of quartzite, most of which range from three to six inches in diameter, larger pebbles of the underlying dolomite, not, however, in any great quantity; the upper bed appears to contain only quartzite and quartz, and passes through grits into the red quartzite.

In this particular section the two conglomerates are separated by a band of finer material, which is of very variable thickness, ranging from about 20 feet to a mere thread, and sometimes dying out altogether: this is the case in the section on the left bank of the Parahio (Pl. VII), where, however, the other characters are the same as those in the section just described.

Near Prádá, in the upper Pin valley, the whole of the silurian system is enclosed in a great synclinal lying on the upper cambrian slates, and cut off on either side by faults. On the opposite side of the river, behind Baldar, this synclinal caps the ridge to the north of the Bhabeh Pass and runs on to the south-east into the valley of the Téti river in Bashahr. The conglomerate forms a very distinct and conspicuous dark band below the red quartzite.

In the valley of the Chokdinjan stream in Bashahr, at about a mile above its junction with the Thanam river, the conglomerate, which lies on the lower beds of the trilobite series, forms a single band 40 feet thick, composed of boulders of slate and quartzite in a red, gritty matrix and passes up gradually through pebble beds and grits into the overlying red quartzite.

Red quartzite.

The red quartzite calls for little notice; except in regard to colour, its characters are constant throughout Spiti and Bashahr. A typical section is seen at about one mile south-west of Muth, where the rock is a dark pinkish-red—at times carmine—quartzite, usually gritty and occurring in beds of about 2 feet in thickness. With it are interbedded thin layers of a lighter coloured shale. The thickness of the whole mass is about 1,500 feet. No trace of fossils was found anywhere in the quartzite or in the shales. In disturbed areas where the rocks have suffered from dynamo-metamorphism, the quartzite has undergone little alteration beyond a loss of colour. This is especially noticeable near Prádá in the Pin valley, below Pámachaung, on the path from Rupa to the Manirang Pass, at Hango, and on the south side of the Hangrang Pass; in the two last-named localities the rock is pale pink, at times almost white, and in the latter case might easily be mistaken for the "Muth quartzite," which, however, belongs to a higher horizon.

Towards the top, the quartzite becomes more thinly bedded and is gradually replaced by flaggy beds and siliceous shales, which pass up into a system of shale, marl and limestone which constitutes the middle division of Stoliczka's "Muth series"; he describes it as a system of

"arenaceous limestone, in parts largely siliceous, with beds of purer limestone of dark colour." The fossils that he obtained from these rocks were, apparently, too fragmentary and too poorly preserved to admit of specific determination, but from their general facies he was disposed to regard them as of silurian—probably upper silurian—age. An examination of the collections made during the last few years proves that this conclusion was correct. The age of the uppermost member of his "Muth series"—the white "Muth quartzite"—is still doubtful, but the beds between it and the red quartzite have now been found to contain fossils of both upper and lower silurian age.

Silurian limestones.

Near Muth, on both sides of the Pin river, good sections of this limestone series are exposed, that on the right bank being, perhaps, the better of the two. Near Shián the red quartzite passes up through thin-bedded red and green quartzites and siliceous shales into the limestones the series falls stratigraphically, and to some extent lithologically, into the following subdivisions:—

White "Muth" quartzite, passing gradually down into

8.	Reddish-brown quartzite, underlain by grey siliceous limestone, weathering red and pink .	about 80 feet.
7.	Grey limestone, weathering red and brown, with red and brown marls	„ 70 „
6	Grey coral limestone	„ 50 „
5.	Shaly limestone, with brachiopods, gastropods, and corals	„ 30 „
4.	Hard, grey dolomitic and siliceous limestone, with grey and green shales	„ 40 „
3.	Dark grey limestone, weathering brown, with *Cystidea* above and brachiopods below . .	„ 30 „
2.	Dark, fœtid limestone, with shaly limestone and shale bands: brachiopods and trilobites . .	„ 200 „
1.	Shaly and flaggy sandstones and quartzite, with *Orthis* and plants, passing down through red and green thin-bedded quartzites and siliceous shales into the red quartzite	„ 150 „

Each of the subdivisions 1 to 8 is more or less fossiliferous.

Fossiliferous horizons.

The only fossils found in the lowest bed (No. 1) were impressions of *Orthis* sp. ind., plant remains, including *Buthotrephis* sp. cf. *gracilis*, Hall, and crinoid stems.

Trilobite limestones.

The overlying limestone (No. 2) contains numerous fossils, chiefly trilobites and brachiopods, the latter belonging to the genus *Strophomena*; the commonest forms are—

Cheirurus cf. *obtusatus*, Cord.
„ sp.
Illænus punctulosus, Salt.
„ sp.
Asaphus cf. *emodi*, Salt., and other species.
Calymene cf. *nivalis*, Salt.
(?) *Bronteus* sp.
Strophomena cf. *alternata*, Sow.
„ *chæmerops*, Salt.
„ *trachealis*, Salt.
„ cf. *lineatissima*, Salt.
Leptæna sericea, Sow.
Orthis, sp.
Tentaculites, sp.
Stromatopora concentrica, Goldf.

Several of the above forms are characteristically lower silurian, and the limestone is probably of Caradoc age. It will be noticed that some of the species have been identified with forms collected by Strachey in Niti [1] and described by Salter.[2] There is, indeed, little room for doubt that the series of limestones, shales and marls between the lower silurian red quartzite and the white (Muth) quartzite of Spiti is the western continuation of the beds from which Strachey's collections were obtained.

Above the trilobite limestone is a band of hard, grey and brown limestone (3), about 30 feet thick, which contains brachiopods in the lower layers, and *Cystidea* in the upper The brachiopods appear to belong chiefly to *Orthis flabellulum*, Sow., with which are associated *Atrypa hemiplicata*, Hall, and corals, chiefly species of *Favosites*.

[1] Quart. Journ. Geol. Soc., vol. VII (1851), p. 303.
[2] Palæontology of Niti.

Near the top of the limestone is a band containing numerous *Cystidea*, chiefly *Pyrocystites pirum*, Barr., and *Craterina* sp.

This bed therefore in all probability belongs also to the lower silurian. It is overlain by about 40 feet of hard, grey limestone and greenish shale, from which no recognisable fossils have been obtained.

The next bed (5) is a shaly limestone, containing numerous badly preserved brachiopods and gastropods, with corals; most of the brachiopods are too badly preserved for identification, but include *Strophomena rhomboidalis*, Wilck., *Meristella* (*Atrypa*) *cylindrica*, Hall, *Orthis* sp.

The gastropods belong to the genus *Pleurotomaria*, and the corals to *Cyathophyllum* and *Chætetes*: *Orthoceras* sp. is also common.

Coral limestone.

This is overlain by about 50 feet of grey limestone, containing large numbers of well-preserved corals, which include—

Halysites catenulatus, Linn.
Chætetes yak, Salt.
Lyellia sp.
Favosites sp.
Cyathophyllum sp.
Syringopora sp. also occurs.

Halysites catenulatus and *Chætetes yak* are very common.

This bed appears to be Mr. Griesbach's "hard, dark, concretionary coral limestone," which he regarded as devonian.

"Red crinoid limestone."

The next bed (7) consists of shaly limestone and grey siliceous and flaggy limestone, weathering bright brownish-red. It contains numerous fossils, mostly, however, preserved only as casts and moulds: in places the weathered surface of the rock is covered with fragments of crinoids; it therefore probably represents Mr. Griesbach's "red crinoid limestone." The shaly bands contain numerous brachiopods, of which the following are the commonest:—

Orthis thakil var. *convexa*, Salt.
" " " *sub-divisa*, Salt.
" cf. *elegantula*, Dalm.
Leptæna depressa, Dalm.
Chonetes sp.

Orthoceras sp. also occurs.

This band probably includes also Mr. Griesbach's "earthy, grey crinoid limestone."

It passes up into a series of hard, light grey, siliceous limestones, which gradually become less and less calcareous, and pass through calcareous quartzite into the reddish and brown quartzites which form the lowest beds of the "Muth quartzite."

These siliceous limestones contain a few fossils, which, owing to the hardness and homogeneity of the rock, can be seen only on the weathered surfaces; they include—

Favosites sp.
Bellerophon sp.

and badly preserved casts of cephalopods. In the Parahio valley, near Gyetzan (Gaichund), the same beds contain also numerous casts of

Pentamerus bed.

(?) *Pentamerus oblongus*, Sow. The rock is unfortunately so hard that fossils cannot be extracted, and the identification of *Pentamerus oblongus* is therefore not absolutely certain, but the specimens seen on the weathered surface correspond so closely with that species that they may be referred to it with a very great degree of probability.

It is evident, therefore, that the whole series included between the

Age of limestone series.

red quartzite below and the white (Muth) quartzite above is of silurian age, and includes both upper and lower silurian beds. The lowest subdivisions (1 to 3) probably include the Caradoc and possibly lower stages, while the coral limestone may perhaps be referred to the Llandovery or Wenlock. These correlations, however, are only tentative, and until the collections have been worked out in detail, it will be impossible to recognise definite horizons with any degree of certainty; nor, indeed, has such detailed work been aimed at in the present memoir, which does not pretend to do more than give a somewhat general account of all the stratified rocks of Spiti, leaving the determination of the smaller subdivisions for future opportunities of detailed study.

The two lower subdivisions of Stoliczka's "upper silurian" or

"Muth series" have now been dealt with and their age determined with a fair degree of certainty. The uppermost member of that series is a hard, white quartzite, frequently containing brown specks of ferruginous matter. About half a mile to the west-south-west of Muth it forms a great wall of rock, nearly five hundred feet high, dipping at about 50° to the north-east. In its lower beds it is brownish and thin-bedded, and passes down very gradually into the grey, calcareous quartzites and siliceous limestones with *Pentamerus oblongus*.

Muth quartzite.

No trace of fossils has been found in the quartzite, and its age can only be inferred from that of the rocks above and below it. There is little doubt that it is immediately underlain by upper silurian beds; above, it passes up gradually into a series of hard, siliceous limestones, the age of which is doubtful, but which, as will be seen in the following chapter, may belong to the devonian system. Hitherto, Stoliczka has stood alone in including the Muth quartzite in the silurian system, and it might seem undesirable, in view of the opinions expressed by subsequent observers, to adopt his classification in the present memoir, but since internal evidence of its age is entirely wanting, it has been deemed advisable to describe it with the rest of the series in which it was originally included. At present it is only possible to assert that its age is either upper silurian or devonian, and until more detailed researches shall have fixed definite horizons above or below it, the question must remain open.

In the "Manual of the Geology of India," the Muth quartzite has been included in the carboniferous system. This is mainly in consequence of the observations of Mr. Griesbach in the Kumaon and Garhwál Himálayas, and subsequently in Spiti. By Mr. Oldham, also, it was correlated with a certain white quartzite found in Kashmir among beds yielding a carboniferous fauna. This correlation was apparently based on its lithological resemblance to the Kashmir rock and also on its position at the base of Stoliczka's carboniferous "Kuling series." The only sections found along the route traversed by Mr. Oldham, *viz.*, those at Muth and Kuling, would seem to support this view, but subsequent

examination of a wider area has proved that the sequence, as seen at these two villages, is very incomplete, for in other localities the carboniferous rocks include several bands of quartzite, all exactly similar to one another and to the Muth quartzite, while one of the highest of these occurs immediately below limestones containing a rich carboniferous fauna.[1]

Eastern representatives of Muth quartzite.

In Kumaon and Garhwál a white quartzite has been described by Mr. Griesbach as overlying his "red crinoid limestone," and has been identified by him with the Muth quartzite,—an identification which is almost certainly correct. Since he believed the "red crinoid limestone" to be lower carboniferous, he naturally referred the white quartzite to the upper part of the same system. It has, however, now been ascertained that the Spiti representative of the "red crinoid limestone" is certainly not younger than upper silurian, and in view of the gradual passage between it and the Muth quartzite, and the complete absence of unconformity, it is safe to assert that the latter formation is not younger than devonian.

Extent of silurian system.

The silurian system, as described above, extends with little variation throughout the whole of Spiti. To the south-east it passes over the dividing range into the valleys of the Thanam and Téti rivers in Bashahr (Pl. X), and can be traced along the hills on the left side of the Thanam valley to the Hangrang Pass. In this area it is of smaller extent than in Spiti, having been greatly eroded in permian times (Pl. XI); in places the whole of the Muth quartzite and silurian limestone have been removed and the permian beds are found resting on the red, lower silurian quartzite. Similar erosion of the Muth quartzite was noticed by Mr. Griesbach in Niti.[2]

To the north-west the silurian beds are found at Trákse, near Losar in upper Spiti, on the road to the Kunzam Lá, where they are

[1] It is not, however, intended to imply that this quartzite is necessarily the equivalent of the Kashmir band.

[2] Memoirs, G. S. I., vol. XXIII, p. 62.

considerably crushed and faulted, but in other respects similar to the type series at Muth. From the summit of the Kunzam Pass they can be seen running northwards along the left side of the Chandra valley, and, further on, their presence has been recorded by Stoliczka in North Lahaul.[1] Here he found traces of *Orthis* and trilobites in a light-coloured limestone, which, however, he referred to his Bhabeh series (cambrian of this memoir). It is possible that the limestone may represent the cambrian dolomite of the Parahio, but there is no trace of this rock in the intervening area, *i.e.*, in upper Spiti and on the Kunzam Lá, where the lower silurian conglomerate rests on the lower beds of the upper cambrian, and it is probable that the Lahaul rock is really silurian. This, unfortunately, cannot be ascertained by reference to Stoliczka's collections, which, with the rest of his and Mr. Griesbach's palæozoic fossils, have been for many years in England awaiting description.

Possible representatives in Kashmir.

How far this system may be represented in Kashmir it is at present impossible to say. The lower conglomerates and quartzite may possibly find their equivalents in Lydekker's Panjál system, to which they appear to have some lithological resemblance, but, as will be seen below (p. 57), certain beds, which occur at a very much higher horizon, have also lithological characters very similar to those of the Panjál rocks, and it is therefore unsafe to attempt any correlation on this basis. Nor do the stratigraphical features of the Panjal rocks offer any assistance, for they do not appear to include any fossiliferous beds similar to either the cambrian or the silurian of Spiti, while their structural conditions are so highly complicated by supposed inversions of the strata, that in many cases their true relations to the now under- and over-lying beds may be the reverse of what they appear, and until fossils have been found in the older palæozoic rocks of Kashmir, the only hope of correlating them with those of Spiti will lie in tracing the series of known age continuously from one area into the other.

[1] Memoirs, G. S. I., vol. V, p. 341.

In the face of such difficulties in the immediate neighbourhood of Spiti, it might seem futile to go still further afield, and beyond Kashmir, in search of an equivalent of the silurian system of Muth, but it is necessary to refer to an interesting paper recently published by General McMahon and Mr. Hudleston,[1] dealing with a series of fossils collected by Captain Gurdon on the bank of the Chitral river, between Chitral and Mastuj. An account of the rocks of the locality was contributed by Major McMahon, who mentions three distinctive horizons, *viz.*, a conglomerate, a red sandstone, and a limestone. The conglomerate is the lowest, and is overlain by the red sandstone. The limestone, which is the uppermost member of the series, yielded the fossils which have been described by Mr. Hudleston, who considers that they are undoubtedly devonian. Major McMahon does not say whether the limestone *immediately* overlies the red sandstone or is separated from it by other beds, but his diagrammatic sketch[2] does not preclude the latter possibility. Should the conglomerate and sandstone correspond to the conglomerate and red quartzite of Spiti, the devonian limestone might be the equivalent of the limestones which immediately overlie the Muth quartzite, and which may very possibly be of devonian age.[3]

Red sandstone, conglomerate and devonian limestone of Chitral.

[In this connection it is interesting to note that a few years ago a small collection of fossils was sent to the Geological Survey of India by Lieutenant Grant from the Baroghil Pass in Chitral. They consist of fragments of a trilobite (*Phacops* sp.), a *Spirifer, Orthis,* and some *Bryozoa* in a compact, grey limestone The materials are not sufficiently good to admit of specific determination, but they resemble devonian species.]

In the annexed table will be found the correlation and subdivisions of the lower palæozoic beds of Spiti adopted respectively by Stoliczka, Griesbach and the present writer.

Subdivision and correlation of lower palæozoic beds.

[1] Geol. Magazine, January and February 1902.
[2] Geol. Magazine, January 1902, p. 5, fig 2.
[3] *Infra*, p. 34.

Stoliczka. (Memoirs, G. S. I., vol. V.)		Griesbach. (Memoirs, G. S. I., vol. XXIII.)			Present Memoir.		
Muth quartzite.	(?) UPPER SILURIAN.	White (Muth) quartzite.		CARBONI-FEROUS.	Muth quartzite.		(?) UPPER SILURIAN.
Arenaceous and siliceous limestone.		Red crinoid limestone.			Grey siliceous limestone, weathering red.	Upper	SILURIAN.
		Earthy, dark grey limestone.			Grey limestone, weathering reddish brown, with brown and red marls.		
		Hard, dark concretionary coral limestone, with splintery shales.		(?) DEVONIAN.	Grey coral limestone.		
					Shaly limestone, with *brachiopods*, *gastropods* and *corals*.	(*Boundary doubtful.*)	
					Hard, grey dolomitic limestone.	Lower	
					Dark grey limestone, with *Cystidea*.		
					Dark, fœtid limestone, with *trilobites* and *brachiopods*.		
					Shaly and flaggy sandstone, with *plants*.		
Purple quartzite, with conglomerate at base.		Dirty, flesh-coloured quartzite.	Upper	SILURIAN.	Flaggy quartzite and siliceous shale passing down into great mass of red quartzite, underlain by conglomerate.		
		Thin-bedded, dark grey coral limestone.	Lower				
Green and bluish micaceous and laminated sandstones. Grey siliceous sandstone, with occasional calcareous beds (dolomitic), with blue and red shales.	LOWER SILURIAN.	Red quartz shales.	Upper	HAIMANTA.	Black shales and slates, with green and brown quartzites, and (locally) bands of dolomite, red and green quartzites at base.	Upper (and (?) partly Middle)	CAMBRIAN.
					Blue and black slates (weathering bright red), with carbonaceous shales.		
Bluish grey slates and sandstones.		Slates, quartzites and conglomerates.	Middle and Lower		Slate and quartzites.		

CHAPTER IV.

DEVONIAN (?), CARBONIFEROUS AND PERMIAN.

Recent discovery of devonian beds in Burma,

It is a curious fact that although rocks of devonian age had long been known to occur on either side of the Indian Empire, yet, until quite recently, none had been found in the intervening area. During the field season of 1899-1900, Mr. T. D. La Touche, assisted by Mr. P. N. Datta, made the first discovery of devonian fossils, in the Northern Shan States, and during the subsequent season, Mr. La Touche succeeded in obtaining a large collection of well-preserved and thoroughly characteristic species. Almost simultaneously with Mr. La Touche's discoveries in the most easterly part of the Empire, the collection of devonian fossils mentioned in the last chapter was made by Captain Gurdon, in the Hindu Kush, thus bringing the devonian beds almost to the confines of the Himálayas, but as yet no fossils which could be unequivocally referred to that system have been discovered in this great mountain range.

and in the Hindu Kush.

In the Niti area and in Spiti, Mr. Griesbach has described a "hard, dark, concretionary coral limestone," varying in thickness from 650 to nearly 1,000 feet, which he believed to be of devonian age. This correlation, however, is not based on the evidence of fossils, but depends on the fact that the limestone overlies the red quartzite, regarded by him as of upper silurian age, and underlies the "red crinoid limestone" which he ascribed to the carboniferous system. From the section south of Muth, in Spiti, he describes his devonian system as "a thickness of from 700 to 800 feet of a very dark, hard limestone, concretionary in parts, alternating with dark, splintery shales."[1] This can only represent the limestone series, described in the last chapter, which overlies the red silurian quartzite and has now been found to

[1] Memoirs, G. S. I., vol. XXIII, p. 214.

contain lower, and probably also upper, silurian fossils. It is evident, therefore, that the Himálayan equivalent of the devonian system must be sought for at a higher horizon, which, as already shown, must be situated at least above the base of the Muth quartzite.

Devonian in Bashahr.

In the valleys of the Lipak and Yulang rivers in Kanaur, this quartzite passes up, through shaly beds and narrow bands of quartzite, into a series of siliceous and shaly limestone, with hard, nodular, coral-bearing bands. At about 80 feet above the Muth quartzite is a bed of grey limestone containing corals, crinoids and brachiopods. The matrix is very hard and siliceous, and the fossils are most clearly seen on the reddish-brown weathered surface of the rock. They are unfortunately all badly crushed and cannot be determined with any degree of certainty, but the brachiopods include large numbers of a form very closely resembling *Strepterhynchus umbraculum*, Schloth., with species of *Orthis*, *Atrypa aspera*, Schloth., and *Cyathophyllum* sp. These beds form the base of a series of dark, splintery limestones, about 300 feet thick, in which, with the exception of four bands of coral limestone, no other fossiliferous horizons have been found.

The coral bands occur at intervals through the limestone, and vary in thickness from 1 to 3 feet. They appear to be composed entirely of a species of *Cyathophyllum*, but the original fossils have been almost entirely replaced by crystalline calcite and silica, and their internal structure to a great extent obliterated. It is possible that this series may represent the whole or a part of the devonian system, but in all the localities visited, the fossils are too badly preserved for reliable determinations.

It has already been stated that the palæozoic beds have undergone erosion, which took place between carboniferous and permian times; owing to this, the limestone just described is frequently wanting in the palæozoic sections. In Spiti, however, it is found at Trákse, near Losar, where it is greatly crushed, but contains brachiopods similar to those found in the Yulang valley. The same beds probably occur at Muth also, but no determinable fossils have been found.

It was believed by Stoliczka that the palæozoic systems of Spiti comprised two distinct facies, termed by him the *southern* and the *eastern* respectively. The *southern* facies was that exposed in the Pin valley, where the section includes the older palæozoics described in the last two chapters, and regarded by Stoliczka as silurian. In the *eastern* facies he included a great series of shale and quartzite found in the lower Spiti valley, at and beyond the village of Po; this he identified with his Bhabeh and Muth series, considering it probable that the relationship of the two facies to one another would be ascertained by an examination of that part of Kanaur lying immediately to the south-east of Spiti. This area was examined for the first time in any detail by the present writer in 1899, and it was definitely ascertained that the eastern was not the equivalent of the southern series, but was very much younger.

Stoliczka's "southern and eastern facies."

At Muth the white (Muth) quartzite passes up through arenaceous and shaly beds into a mass of dark limestone, which has a thickness of between 300 and 400 feet, and has yielded a considerable number of fossils, mostly, however, rather badly preserved. Further down the Pin valley, at Kuling, the same limestone is again seen; it is perhaps a little thicker here, but is in other respects similar to that seen at Muth. At each of these localities the limestone is overlain unconformably by a conglomerate followed by a bed of calcareous sandstone and black shales (the "Productus shales"). It will subsequently be seen that these upper beds are of permian age.

Carboniferous beds at Muth.

The unconformity between the permian beds and the underlying limestone was first noticed by Stoliczka and subsequently confirmed by Griesbach, who had also observed a similar break at the base of the permian beds in the more easterly parts of the Central Himálayas.[1] As the horizon of the white quartzite is followed from Muth towards the south-east, the permian beds are found to rest on lower and lower horizons of the underlying

Carboniferous-permian unconformity.

[1] Memoirs, G. S. I., vol. XXIII, p. 63.

systems, till in the Thanam valley they lie on the red, lower silurian quartzite; as they are traced further eastwards, the upper beds of the silurian re-appear, till at length, near Hango in Kanaur, a few patches of the Muth quartzite are found; these gradually pass into the full thickness of that formation, and in the valley of the Lipak river, the upper palæozoic systems occur in the fullest development to which they have hitherto been known to attain in the Himálayas.

Carboniferous limestones of Kanaur.

Here the Muth quartzite is overlain by a series of limestone and quartzite over 2,000 feet thick, which is in turn succeeded by an even greater thickness of dark shale and quartzite, passing up near Po, in the Spiti valley, into conglomerate and calcareous sandstone, which immediately underlie the permian "Productus shales." This great series, the total thickness of which, including the "Productus shales," cannot be less than 5,000 feet, represents the carboniferous and permian—and probably also devonian—systems of the Himálayas.

Lithologically, the series falls into two subdivisions, a lower consisting of quartzite and limestone, and a higher composed of quartzite and shale.

The lower subdivision is found in its fullest development in the hills above Lio in Kanaur, where it forms the ridge separating the Lipak and Yulang rivers. At the opposite end of Spiti, at the head of the Spiti river, it is also largely developed, but the total thickness is probably less than in Kanaur; the beds, however, are crushed and faulted, and only a few of the Lipak horizons can be recognised.

At the point where the upper mountain track to Hango leaves the Lipak river, the hills on either side of the stream rise sharply up in steep precipices to a height of some 4,000 feet above the river; those on the left bank form one side of the ridge which separates the Lipak and Yulang rivers. Near the summit of the ridge is the camping-ground of Tangá, between which and the river below the rocks afford a section of almost the whole of the silurian system, with the Muth quartzite and the overlying limestone and quartzite series. Near the middle of the section a bright, reddish-

brown band represents the weathered silurian limestone, above which the white Muth quartzite forms an equally striking horizon.

Thickness.

The total thickness of the succeeding limestone and quartzite series is probably almost 2,000 feet; the section was measured from the top of the Muth quartzite up to the camping-ground of Ták-rá-chen, which is a little below Tangá, but owing to the physical difficulties involved, the following measurements are only approximate:—

"Po series" of shale and quartzite.

7. Yellow and buff limestone. Dark, flaggy limestone, hard and splintery	500 feet.	
6. Limestones, with thin bands of soft shale; fossiliferous horizons occur at the following heights above the white quartzite No. 5:—		
Grey shale (horizon *g*), 372 feet above No. 5		
Limestone *f*), 303 „ „		
Shale *e*), 263 „ „		372 „
Limestone *d*), 188 „ „		
Shale *c*), 123 „ „		
Shale *b*), 117 „ „		
Flaggy limestone. *a*), extending from 12 feet to 37 feet above No. 5		
5. White quartzite		25
4. Hard, dark limestone, containing apparently only crinoids		185
3. White and grey quartzite, with purple slates and subordinate bands of flaggy limestone		224
2. Limestone, weathering yellow and reddish-brown		131
1. Hard, dark grey and black splintery limestone in beds of from 2 feet to 4 feet thick, with coral bands at 283′—4′, 262′—5′, 152′—5′, 95′—97′		360 „
Total thickness		1,797 feet.

Muth quartzite.

Fossiliferous horizons.

The lowest subdivision (No. 1) of the above series has already been described. With the exception of the bands of corals, no fossils were found in it between the Lipak river and Ták-rá-chen: sections of brachiopods were seen in the rock, but nothing could be extracted. On the opposite side of the ridge at about 1,000 feet above the Yulang river, the fossils

already mentioned (*supra*, p. 34) were found; as stated above, they are too badly preserved to afford definite proof of the age of the limestone, but it may perhaps represent part, at least, of the devonian system.

With the exception of crinoid remains in No. 4, the overlying beds (2 to 5) have yielded no fossils, and their age is therefore uncertain. The two quartzites, Nos. 3 and 5, closely resemble the Muth quartzite, for which they might very easily be mistaken. They are seen in the Yulang river and again at Gyumdo E. G. on the left bank of the Spiti river, in the Tibetan province of To-tzo (or Tso-tso), where they and the accompanying limestones have been greatly altered by contact-metamorphism. Here they were supposed to represent the Muth quartzite, but the subsequent discovery of the series in the Lipak river proved that this correlation was erroneous.

The third quartzite (No. 5) passes up into a series of limestones (6) with thin partings of shale. This subdivision is more or less fossiliferous throughout its whole extent, but the beds have been often much crushed and folded, and the fossils are in many cases too badly preserved for identification. Certain horizons, however (*a* to *g*, Pl. II), were found, in which the fossils were in a very fair state of preservation, and from these a large collection was obtained.

Horizon (*a*).—The lowest horizon (*a*) occurs about 12 feet above the uppermost white quartzite (No. 5), and consists of a highly fossiliferous band of rock of about 25 feet in thickness. The specimens obtained from this bed include the following forms:—

Productus cora, d'Orb.
" *semireticulatus*, Mart.
" sp.
Chonetes hardrensis var. *tibetensis*, Dav.
Syringothyris cuspidata, Mart.
Spirifer cf. *kashmiriensis*, Dav.
" sp.
Strophomena analoga, Phill.
Reticularia lineata, Mart.
Athyris royssii, Lév.
" *subtilita*, Hall.
(?) *Retzia* sp.

Discina sp.
Conocardium sp.
Aviculopecten sp.
Platyceras sp.
Pleurotomaria sp.
Phillipsia cf. *cliffordi*, Woodw.
Helodus crenulatus, Newberry and Worthen.
Polypora sp. and numerous crinoids.

With these occur numerous specimens of *Orthotetes* sp. or *Derbyia* sp., resembling *D. senilis*, Phill., but the internal characters cannot be distinguished, and it is consequently impossible to refer them definitely to either genus.

There can be no doubt that the age of the beds in which the above fossils occur is carboniferous, and though some of the forms are common to the whole of that system, yet, from the presence of *Syringothyris cuspidata, Phillipsia* cf. *cliffordi* and *Helodus crenulatus*, it seems probable that the limestone is of lower carboniferous age. The same horizon has been recognised at Muth and Kuling in the Pin valley and Trákse, near the head of the Spiti river.

Horizon (*b*).—This is a band of shale, 3½ feet in thickness, which occurs at about 117 feet above the top of the white quartzite (No. 5).

The fossils, though numerous, are much crushed and are often merely casts or impressions; they consist chiefly of large numbers of—

Spirifer sp.
Discina nitida, Phill.
„ cf. *newberryi*, Hall.
Lingula cf. *mytiloides*, Sow.
Pleurotomaria sp.
Retzia sp.

Horizon (*c*).—About six feet higher up another band of shale contains impressions of—

Spirifer sp.
Rhynchonella pleurodon, Phill.
Aviculopecten sp.
Orthoceras sp.

The *Spirifer* and *Rhynchonella* are very common.

Horizon (*d*).—This horizon consists of a highly fossiliferous band

of limestone, occurring at about 188 feet above the quartzite (No. 5); it has yielded the following forms:—

Productus cora, d'Orb.
„ *semireticulatus*, Mart.
Syringothyris cuspidata, Mart.
Spirifer, sp.
Rhynchonella pleurodon, Phill.
„ „ var. *davreuxiana*, de Kon.
Athyris royssii, Lév.
„ *subtilita*, Hall.
Chonetes hardrensis, Phill.
Strophomena analoga, Phill.
Aviculopecten sp.
Euphemus urii, Fleming.
Pleurotomaria sp.
Platyceras sp.
Conularia cf. *quadrisulcata*, Miller.
Chætetes radians, Fisch.

It will be seen that the forms found at this horizon are to a great extent the same as those obtained from the lowest band (*a*), and it is therefore probable that the whole series from the top of the white quartzite (No. 5) to this horizon is of lower carboniferous age.

Horizon (*e*).—At about 75 feet above the last horizon, a band of shale, 1 inch in thickness, has yielded the following forms:—

Rhynchonella pleurodon, Phill.
Chonetes hardrensis, Phill.
Spirifer sp.
Discina cf. *newberryi*, Hall.
Orthoceras sp.
Psammodus sp.

and numerous casts of a bivalve. Immediately above this is a band of limestone with—

Productus cora, d'Orb.
Rhynchonella pleurodon, Phill.
Orthotetes (?) sp.
Aviculopecten sp.
Euomphalus sp.[1]

[1] This is a small specimen closely resembling *E. hecale*, Hall, from the devonian of New York.

Horizon (*f*).—Forty feet higher up another band of limestone contains numerous fossils including—

Productus cora, d'Orb.
Productus semireticulatus, Mart.
Spirifer sp.
Athyris royssii, Lév.
Rhynchonella pleurodon, Phill.
Orthotetes (?) sp. (or *Derbyia* sp., resembling *Derbyia regularis*, Waagen).
Terebratula sp.
Fish teeth.

Horizon (*g*).—The highest horizon in this series at which fossils were found is a band of light grey, micaceous shale, 372 feet above the white quartzite (No. 5). This bed contains immense numbers of *Estheria* sp.; they all appear to belong to the same species, which is probably new and does not therefore throw any further light on the age of the shale.

It will be seen from the above lists of fossils, imperfect though they are, that most of the forms found in the lowest horizon (*a*) occur also at higher horizons, and it is therefore probable that the whole series from the top of the white quartzite (No. 5) to the *Estheria* bed, belongs to one and the same subdivision of the carboniferous system, while the presence of *Syringothyris cuspidata* renders it probable that that subdivision is the lower.

The fossiliferous beds pass up into a mass of limestone about 500 feet thick, of which the lower beds are hard, dark and flaggy while the upper consist of yellow and buff crystalline limestone. In the Lipak and Yulang valleys the uppermost beds have been in many places converted into a very pure, white gypsum. Similar alteration of the carboniferous limestone has taken place at several other localities, including Gyumdo E. G. in To-Tzo, Huling in lower Spiti, the Sumra Lá (between Sumra and Shálkar), Tangá Chenmo in the Gyundi valley in upper Spiti, and above Trákse E. G. near the head of the Spiti river. This alteration is not confined to the upper beds, but occurs at various horizons in the carboniferous limestones.[1]

[1] For a fuller description of the gypsum, see below, p. 101.

The thickness and extent of these beds overlying the Muth quartzite is very variable. They occur in their fullest development in the section just described. In the Thanam valley they have been completely removed by permian or pre-permian denudation, but re-appear to some extent in Spiti, and at Muth in the Pin valley are represented by about 450 feet of siliceous limestone, calcareous sandstone and dark, fossiliferous limestone. At about the middle of the series the limestone contains large numbers of *Syringothyris cuspidata*, Mart., *Spirifer* sp., *Dielasma* sp. and *Rhynchonella pleurodon*, Phill., and 50 feet lower down a band was found almost entirely composed of *Rhynchonella pleurodon*. These beds almost certainly represent the fossiliferous limestones (No. 6) of the Lipak river, but the underlying beds which, in the latter locality, are about 1,000 feet thick must be represented at Muth by less than 100 feet of limestone, calcareous sandstone and quartzite, and since the horizontal distance between Lio and Muth is only between 30 and 40 miles, this must involve a remarkably rapid thinning out of the lower beds from east to west.

Thickness of carboniferous system very variable.

Carboniferous at Muth.

To the north of Muth, at Kuling on the Pin river, the beds immediately below the permian unconformity are dark, flaggy limestones, apparently unfossiliferous, but underlain by a limestone very similar to horizon (*a*) of the Lipak section. The commonest fossils are—

Carboniferous at Kuling.

Productus cora, d'Orb.
„ *semireticulatus*, Mart.
Rhynchonella pleurodon, Phill.
Syringothyris cuspidata, Mart.

With these occur also—

Reticularia lineata, Mart., and *Orthotetes* (or *Derbyia*) sp.

This band, which is seen just below the path from Kuling to Kungri, and again on the road from Kungri to Mikkim, is underlain by a thin bed of quartzite which passes down into hard limestones and quartzites overlying the Muth quartzite. The beds below the fossiliferous lime-

stone appear to be thinner than in the Lipak section but t icker than at Muth.

Among the Kashmir and Spiti fossils described a few years ago by Professor Diener are two badly preserved specimens of a form identified by him with *Syringothyris cuspidata*, Mart.[1] They are said to have been "obtained near Kuling in Spiti, by Dr. Stoliczka, from a black crinoidal limestone." Professor Diener continues as follows: "There is some probability of this rock specimen having been derived from the crinoid limestone horizon which Griesbach has demonstrated to underlie the white quartzite of Spiti, and which he correlates with the mountain limestone of Europe. If this probability could be proved, the presence of *Syringothyris cuspidata* would be strongly in favour of Griesbach's correlation." [2] The limestone referred to is Griesbach's "earthy, grey crinoid limestone" which constitutes bed No. 7 of his sequence (Memoirs, G. S. I., vol. XXIII), and which underlies the "red crinoid limestone." At Muth, however, the grey limestone in question has already been shown to be certainly not younger than upper silurian, nor does it in any respect resemble the black oölitic and crinoidal limestone in which *Syringothyris cuspidata* occurs both at Muth and at Kuling: the latter limestone is, in fact, Griesbach's "upper carboniferous (8*a*)," and the presence in it of *Syringothyris cuspidata* [3] is, as Dr. Diener remarks, strongly in favour of its being of *lower* carboniferous age. It may be added that Griesbach's "earthy, grey crinoid limestone," is not seen at Kuling, nor, indeed, within many miles of that village, the lowest bed exposed being the Muth quartzite, which forms the core of an anticline between the villages of Khár, on the right bank of the Pin river, and Kungri, on the left; only the uppermost part of the quartzite is seen at the river-side below

[1] Since the above was written, Professor Diener's descriptions of the Spiti fossils, collected by Dr. von Krafft and the present writer in 1899, have reached India and are being published in Pal. Indica, Himalayan Fossils, vol. I, pt. 5. With regard to the identification of the Spiti fossil with *Syringothyris cuspidata*, Mart., see pp. 147-150 and Appendix to that memoir.

[2] "Anthracolithic fossils of Kashmir and Spiti," Pal. Indica, ser. XV, vol. I, pt. 2, p. 76, and pl. IV, figs. 9, 10.

[3] *Ibid*, p. 95.

Kuṇgri, while the limestone with *Syringothyris* is well exposed near the village, although that fossil is not perhaps so common as either at Muth or in the Lipak section.

Carboniferous in the Parahio, Rátang and Gyundi valleys.

To the north-west of Muth, in the valley of the Parahio, near the village of Gyetzan (Gaichund), the carboniferous beds and the greater part of the Muth quartzite have been cut out by a fault, but re-appear in the upper reaches of the Rátang (Pl. I, fig. 1) and Gyundi rivers (Pl. III, fig. 1), where their thickness is little, if at all, greater than at Muth. In the high ranges, however, between the Gyundi river and the village of Losar, the beds rapidly thicken, and near Trákse, at the head of the Spiti river, the series is thicker than in any other part of Spiti, though apparently not so thick as in the Lipak valley in Kanaur. At Trákse the beds have been greatly disturbed and crushed,

Carboniferous of upper Spiti.

but still contain numerous fossils, which are, however, badly distorted. The lowest horizon recognised is that containing (?) *Streptorhynchus umbraculum*, Schloth., and other brachiopods, already described from the Yulang valley as of possibly devonian age (*supra*, p. 34). This is overlain by limestone and quartzites, above which are flaggy limestones, representing horizon (*a*) and containing large numbers of distorted specimens of *Productus*, *Chonetes* and *Rhynchonella*: the beds between these two fossiliferous horizons are about 500 feet thick. The upper horizon is overlain by a series of flaggy limestones, which represent the uppermost subdivisions (Nos. 6 and 7) of the Lipak series.

Before attempting to correlate these beds with supposed carboniferous rocks of other areas, it will be advisable to describe the overlying shales and quartzites, which are found in upper and lower Spiti and Kanaur, and which constitute Stoliczka's "eastern facies." Owing to their remarkable development in the neighbourhood of Po, they may be conveniently termed the "Po series." [1]

[1] In spite of the desirability of eliminating local names, this is not possible in the present instance, for the age of these beds is still uncertain and they cannot be definitely referred to either of the upper palæozoic systems.

Po series.

At the head of the Lipak river, the uppermost carboniferous limestones are overlain by alternating beds of shale and quartzite. The thickness of the series is variable: it appears first on the right side of the Lipak river, where the total thickness of the shale and quartzite is small, but to the north, towards Spiti it increases, and in the ranges on either side of the Spiti river below Po it is not less than 2,000 feet. Near Sumra and Lari the lower beds of the series consist of shale and quartzite, the former predominating. The quartzites are yellowish, brownish or white, and often resemble the Muth quartzite. The shales are usually black, but near Sumra are reddish-brown and schistose; this is due to contact-metamorphism, numerous dykes and sheets of basic igneous rock (amphibolite and altered dolerite) occurring among the sedimentary beds. In the neighbourhood of the intrusions, the shales have been converted into hard slates and pyritous and garnetiferous mica schists. One of these dykes runs for several miles along the hillside between Sumra and the pass (Sumra Lá or Shálkar Lá) leading into Kanaur, and is seen again in the hills on the left side of the Spiti river, opposite Sumra; it is of very uniform thickness and is inclined at a low angle to the bedding-planes of the shale and quartzite: it thus frequently resembles, and is at times, a sheet, and it is probable that it was mistaken by Stoliczka for a contemporaneous trap flow, for he states that "between Changrizang and Po. . . . . beds of greenstone [occur] all through the series . . . . . not in veins, but in regular beds between the other rocks."[1] A careful examination was made by the present writer of all the igneous rocks seen between Po and Changrizang, and in every case they have been found to be intrusive, and although, at times, they take the form of sheets, yet if followed for any distance, they invariably cut across the bedding-planes of the sedimentary beds. These apparent sheets can be seen in the neighbourhoods of Sumra and Lari, while near Po—about ¾ mile north-east of the village—the path

Supposed contemporaneous trap.

[1] Memoirs, G. S. I., vol. V, p. 20.

passes over a mass of dolerite which has been intruded along a fault running at right angles to the strike of the shales and quartzites. This point is one of considerable importance, for the supposed existence of contemporaneous trap-flows in these beds in Spiti has been used as an argument in favour of their correlation with Lydekker's "Panjál, system" of Kashmir.

Normally, then, the series overlying the carboniferous limestones consists of dark shales and quartzites: in the lower part of the series shales predominate, but towards the top the two rocks alternate rapidly and the quartzite bands increase in thickness, till the series becomes one of quartzite and grit—often calcareous—with thick beds of coarse conglomerate; these pass up into a gritty, calcareous sandstone, from 40 to 150 feet thick, overlain by a bed of black and dark brown shale (the "Productus shales"). The two last-named beds—calcareous sandstone and Productus shales—are invariably present throughout Spiti and Bashahr, and constitute the uppermost members of the palæozoic group. As already stated, they are in most sections unconformable to the beds on which they rest, but in the northern parts of Kanaur, and in upper and lower Spiti, the underlying beds occur in their fullest development, and there is no evidence of unconformity, for the conglomerates pass up gradually, through calcareous grits, into the calcareous sandstone.

The complete sequence of the upper palæozoic systems is therefore as follows:—

5. Productus shales:	
4. Calcareous sandstone:	Permian.
3. Conglomerate, grit and quartzite: passing down into	
2. An alternating series of shale and quartzite:	Upper carboniferous and Culm.
1. Limestones and quartzites of the Lipak river.	Lower carboniferous and devonian.

The lowest group (No. 1) has already been described.

In the next group fossils are very rare, and have been found only at three horizons between Po and Thábo. The lowest horizon is a band of green and greyish-green shales, which is exposed on the left bank of the Spiti river, about 1½ mile above Thábo. The only outcrop hitherto observed occurs under a band of quartzite at the water's edge, and during the summer floods is frequently inaccessible. It has yielded only poorly preserved plants; these, however, have been examined by Professor R. Zeiller, to whom the writer is greatly indebted for the following note sent through Mr. R. D. Oldham:—

Culm. Plant beds.

"The specimens collected in Spiti by Mr. Hayden comprise a fragment of a simply pinnate frond and numerous pinnulæ of a fern with cyclopterid venation, which does not appear to differ appreciably from *Rhacopteris inæquilatera*, O. Feistmantel (*non* Goeppert sp.) from the Culm of Smith's Creek, Port Stephens, and Arowa, New South Wales. I have noticed also a very small fragment of a pinna of another fern very similar to *Sphenopteridium furcillatum*, Ludwig (sp.), from the Culm or devonian of Hesse-Nassau, but the specimen is too fragmentary for specific determination. There are also small fragments of a fern recalling *Sphenopteris rigida*, Ludwig, from the same formation, but which are still less fit for definite identification. It is difficult to draw any certain conclusion from these materials as to the age of the beds in which they occur, yet the identity of the fern most largely represented with *Rhacopteris inæquilatera* from the Culm of New South Wales seems to me sufficiently probable to warrant the inference that the beds belong to the same horizon as those of Arowa and Port Stephens." [1]

[1] "Les échantillons recueillis à Spiti par M. Hayden comprennent un fragment de fronde simplement pinnée et de nombreuses pinnules d'une *Fougère* à nervation cyclopteroïde, qui me paraît ne différer par aucun caractère appréciable du *Rhacopteris inæquilatera*, O. Feistmantel (*non* Goeppert sp.), du Culm de Smith's Creek, Port Stephens et Arowa dans la Nouvelle-Galles du Sud. J'y ai remarqué en outre un très petit fragment de penne d'une autre *Fougère* très analogue au *Sphenopteridium furcillatum*, Ludwig (sp.), du Culm ou Devonien de la Hesse-Nassau mais l'échantillon est trop fragmentaire pour être déterminé spécifiquement. Il en est de même de petits lambeaux de *Fougère* qui rapellent le *Sphenopteris*.

It is highly probable, therefore, that the lower part of the shale and quartzite series is homotaxial with the Culm, while it is particularly interesting to note that the only form which has been identified with any certainty belongs to an Australian species. The presence of Culm beds overlying the limestones of the Lipak river is a further proof, if such were needed, that the latter should be referred to the lower, and not to the upper, carboniferous.

Shale with concretions.

Two other horizons are seen in the ridge north-east of Po, a few hundred feet above the path to Thábo. The lower horizon is a black shale with concretions, which frequently contain well-preserved fossils, chiefly *Brachiopoda*. The shales in this locality are everywhere full of concretions, but although many hundreds of these have been broken open, they have been found to contain fossils at only this one horizon, which consists of two rows of concretions separated from one another by about two feet of shale; in the lower row, fossils are rare and consist chiefly of species of *Nautilus*, while the upper band contains *Brachiopoda* and *Bryozoa*.

The small collection of fossils obtained from this horizon comprises the following forms:—

Productus scabriculus, Martin.
" *lineatus*, Waagen.
Dielasma, sp.
Spirigera sp. cf. *gerardi*, Diener.
Reticularia lineata, Mart.
Spirifer cf. *triangularis*, Mart.
Nautilus sp.
Orthoceras sp.
Pleurotomaria sp.
Fenestella sp.

rigida Ludwig de la même formation, mais qui sont encore moins susceptibles d'une détermination certaine.

En résumé, il est difficile de tirer de ces matériaux une conclusion tout à fait sure en ce qui concerne l'âge des couches dont ils proviennent: cependant l'identité de la *Fougère* la plus abondamment représentée avec le *Rhacopteris inæquilatera* du Culm de la Nouvelle-Galles du Sud me parait assez probable pour me donner lieu de penser que ces couches doivent appartenir à peu près au même niveau que celles d'Arowa et Port Stephens."

Fenestella shales.

Higher up on the same ridge another bed of shale contains immense numbers of *Bryozoa*, with a few badly preserved brachiopods; the collections made from this horizon were sent to Europe for description, and are not therefore available for examination, but the present writer is greatly indebted to Professor Diener, to whom the specimens were sent, for the information that "the *Bryozoa* appear to be identical with the leading species from the Zewán beds of Kashmir." Dr. Diener also adds that "among the *Brachiopoda* there is a species of *Productus* which is either identical with, or very nearly allied to, *P. scabriculus*, Mart."[1]

Owing to the innumerable alternations of exactly similar beds of shale and quartzite, it has been found advisable to take advantage of any peculiarities in order to distinguish the various beds, and in consequence of the large numbers of *Bryozoa*—chiefly belonging to the genus *Fenestella*—found in this band, it has been named the "Fenestella shales."

The same bed crops out again about half way between Po and Thábo (Pl. XII), at Lanjarse E. G., on the left bank of the Spiti river, where the path leaves the level of the stream and turns suddenly up a steep ascent of shale: at the top of the slope the path passes over the same black shales full of impressions of *Bryozoa*, and there is little doubt that the horizon is the same as that seen above Po where, however, the beds have been greatly disturbed by faults and the relative positions of the two fossiliferous horizons there exposed are somewhat doubtful, it being uncertain whether the shale with concretions is in reality older than the Fenestella shales, although the latter appear to occupy a considerably higher horizon.

[1] Since writing the above, the author has had access to Professor Diener's description of the fossils from this horizon; they include—

Productus undatus, Defr.
" *scabriculus*, Mart.
" *nystianus var. lopingensis*, Keyser.
Fenestella sp. ind. aff. *F. plebeia*, M'Coy.
Protoretepora ampla, Lnsd.

Above Lanjarse there is a fairly complete section of the beds overlying the Fenestella shales, but no trace of the band of fossiliferous concretions was found, and it is therefore probable that at Po these two horizons are in their true positions relatively to one another. This could not be ascertained definitely at Lanjarse, for the Fenestella shales, underlain by a bed of quartzite, form the base of the section. It is probable, however, that the two horizons are not separated from one another by more than a small thickness of rock, for the same species of *Bryozoa* are numerous in both, and they should perhaps be grouped together as one horizon; this can only be determined by a more detailed examination of the sections between Po and Thábo, and opposite Thábo, on the right side of the Spiti river; the latter locality, though difficult of access, appears to offer a more continuous section and one well adapted to detailed study.

At Losar, however, near the head of the Spiti river, the Fenestella shales, which are found in the high hills behind the village, contain brachiopods (including *Productus scabriculus*, Mart.) exactly resembling those found in the concretionary band near Po. This constitutes a further argument in favour of including the latter band with the Fenestella shales.

Age of Fenestella shales.

With regard to the age of these beds the collections obtained are, it is feared, too small to offer conclusive evidence, but owing to the presence of such large numbers of *Bryozoa*, it was originally suggested by the present writer [1] that they might correspond to the Zewán beds [2] of Kashmir. This question cannot be decided till the Spiti collections have been worked out in detail: for this purpose, they have, as already stated, been sent to Professor Diener, who has kindly informed the author that he believes the provisional correlation of this horizon with the Zewán beds to be correct. Those beds have been regarded by both Waagen

[1] General Report, G. S. I., 1899-1900, p. 189.

[2] Quart. Journ. Geol. Soc., vol. XXII (1866), p. 29; Journ. As. Soc. Beng., vol. XXXV, p. 128, vol. XXXVI, p. 208; Memoirs, G. S. I., vol. XXII, p. 132; Pal. Indica, ser. XV, vol. I, pt. 2.

and Diener[1] as of upper carboniferous age, and should this correlation be correct, the age of the Fenestella shales should also be upper carboniferous.

On the ridge behind (north-east of) Po, the beds are, as already stated, greatly disturbed and faulted, and the Fenestella shales are only separated from the calcareous sandstone (No. 4, p. 46) by a small thickness of shale and quartzite, the greater part of the conglomerate series having been cut out. Further east, however, towards Thábo, a complete, though slightly faulted, section of the overlying beds is seen in the hills above Lanjarse E. G. Here the Fenestella shales are overlain by thick beds of white and brownish quartzite with equally thick beds of shale. At about 300 feet above the Fenestella shales a band of shale contains fragments of brachiopods and bivalves, but all too badly preserved for determination. The lower shales are usually very fine-grained and argillaceous, but towards the top of the series, where quartzite bands are more numerous, they become siliceous and gritty and occasionally contain thin pebble-beds; higher up the shales disappear altogether and are replaced by quartzites, grits and conglomerates.

Permian conglomerate.

As might be expected in shallow-water deposits of this nature, the conglomerate series varies both in character and thickness. High up on the slopes between Lanjarse and Po the shales contain, near their upper limit, beds of grit and a coarse conglomerate; the latter rock forms a bed about 20 feet thick, overlain by another bed of shale, which is followed by a great thickness of grit, quartzite and conglomerate.

South of Pomarang, on the right side of the Spiti river, the sequence is very similar to that just described. The grits are both coarse and fine, and are composed of angular and rounded fragments of shale and limestone embedded in a coarse, slaty matrix. Similarly the conglomerates are composed of boulders and pebbles of various sizes embedded in a gritty or, at times, a slaty matrix, the rock, when crushed,

[1] Pal. Indica, ser. XV, vol. I, pt. 2, pp. 91, 94.

resembling a slate with embedded boulders of all sizes, ranging up to nearly a foot in diameter. This character is particularly noticeable along the path between Pomarang and Máni on the right side of the river, and also between Po and Dankhar, on the left bank, at a short distance below the point at which the path first begins to ascend on to the mesozoic beds; this locality is mentioned by General McMahon, who correlated the conglomerate with the Blaini boulder-slate of Simla.[1] The same rock crops out again at the junction of the Lingti and Spiti rivers,[2] where it was subsequently examined by Mr. Oldham;[3] who also adopted General McMahon's correlation with the Blaini rock.[4]

Calcareous sandstone.

It has already been stated that the uppermost beds of the palæozoic group consist of a bed of calcareous sandstone overlain by black shales, and that the two beds are seen in all sections, resting at times on the lower silurian quartzite or the upper silurian limestone, as in the Thanam valley; at times on the carboniferous limestone, as in the Pin valley; or underlain, as in lower and upper Spiti and Kanaur, by the conglomerates just described (see Pl. III, fig. 3). The lower part of the calcareous sandstone is coarse and conglomeratic, but the thickness of the conglomerate is often only a few feet. The sandstone is everywhere fossiliferous, but the fossils are usually badly preserved. The collections made from this bed were also sent to Dr. Diener, who has kindly furnished the author with the following list of brachiopods found among them:—

Spirifer fasciger, Keyserling (= *Sp. musakheylensis*, Dav.).
" *nitiensis*, Diener.
" *marcoui*, Waagen.
" *distefanii*, Gemmellaro.
Spirigera gerardi, Diener.
Dielasma la Touchei, Diener (n. sp.).
Streptorhynchus cf. *pectiniformis*, Dav.
Aulosteges cf. *gigas*, Netsch.

[1] Records, G. S. I., vol. XII, p. 63.
[2] *Ibid.*, p. 64.
[3] Records, G. S. I., vol. XXI, p. 151.
[4] See below, chapter VIII.

Throughout Spiti and Bashahr the calcareous sandstone is invariably overlain by a bed, usually from 100 to 150 feet thick, of black or dark brown, often siliceous, shale, with a few thin bands of hard, brown concretionary sandstone near its base. This bed constitutes the "Productus shales," which extend, with little variation, throughout the entire length of the Himálayas from the Nepál frontier to Kashmir.

Productus shales.

When first noticed by Stoliczka in Spiti, these shales were named the "Kuling shales," from the village of Kuling, on the Pin river, where they are well exposed and highly fossiliferous. Stoliczka's nomenclature was adopted by Lydekker in Kashmir, but the term was subsequently rejected by Mr. Griesbach, who substituted the name "Productus shales," and since this term has now been so generally adopted and, owing to the large number of *Producti* always found in the shales, is particularly appropriate, it has also been employed in the present memoir, but Stoliczka's original section at Kuling may still be retained as the type for this part of the Himálayas.

An excellent section is seen on the small ridge behind the village, where the calcareous sandstone (Stoliczka's "quartzite") is overlain by about 150 feet of dark shale, with a few irregular sandstone partings. Above the watercourse which supplies the village, the shales, dipping into the hill, form a steep slope and, near the base of a small cliff which caps the ridge, are overlain by a narrow band of hard ferruginous limestone succeeded by thin alternating beds of shale and limestone; the ferruginous limestone includes Griesbach's "Otoceras beds," which were regarded by him as either of lower triassic age or as permo-trias passage-beds. The underlying shales constitute Stoliczka's "Kuling shales," for which the term "Productus shales" is now substituted.

The limits of this bed are everywhere clearly marked, and the "Productus shales" of Spiti and Bashahr may be defined as a band of dark shale with irregular sandstone partings, included between the top of the fossiliferous calcareous sandstone and the ferruginous limestone containing the zone of *Otoceras woodwardi*, Griesbach.

By the employment of the term "Productus shales," restricted as above, the confusion that has hitherto prevailed with regard to the "Kuling series" will be avoided, for Stoliczka included in that series the beds lying between the Muth quartzite and the triassic limestone, and it should consequently embrace the whole of the carboniferous limestone of Lio in Kanaur, as well as the overlying shales and quartzites of lower Spiti, and since the shales of the Po series are often lithologically indistinguishable from the "Productus shales," the retention of Stoliczka's nomenclature would inevitably lead to confusion.

Throughout Spiti and Bashahr the Productus shales are highly fossiliferous, more especially in the lower part of the series, where numerous brachiopods occur, both in the shale and in the sandstone partings. Although individuals are numerous, only a few species are represented; these include—

Fossils.

Marginifera himalayensis, Diener.
Spirifer rajah, Salter.
" *fasciger*, Keyserling.
Chonetes lissarensis, Diener.
Productus cf. *gangeticus*, Diener.
Spirigera gerardi, Diener.

Numerous concretions occur, both isolated and in bands, throughout the shale, but they rarely contain fossils. In the upper part of the bed, however, about 30 feet below the top, is a band of concretions containing *Ammonoidea*, which consist chiefly of *Xenaspis* cf. *carbonaria*, Waagen, and *Cyclolobus* cf. *oldhami*, Waagen.[1]

Horizon of *Xenaspis* and *Cyclolobus*.

In addition to the above fossils, a few *Bryozoa* and badly preserved plants have been found.

[1] The collections which have now been described by Professor Diener, comprise several new species, including—

Cyclolobus insignis.
" (*Krafftoceras*) *kraffti.*
" (") *haydeni.*

The characters of the Productus shales and the underlying calcareous sandstone are so constant throughout Spiti and Bashahr that descriptions of other sections would be superfluous.

Age of Productus shales.

With regard to their age, their position immediately below triassic beds, as well as their similarity to the permian beds of Painkhanda and Johár, prove that the Productus shales of Spiti should be included in the permian system, while their intimate connection, both stratigraphically and palæontologically, with the underlying calcareous sandstone, favour the inclusion of the latter in the same system, but where the base of that system lies cannot be decided till the Spiti collections have been worked out in detail. For the present, it is only possible to say that the Productus shales are certainly permian and the calcareous sandstone and conglomerate series almost certainly so.

In the Salt Range *Xenaspis carbonaria* and *Cyclolobus oldhami* were described by Waagen from the upper Productus limestone, but more recently Dr. Noetling has placed the zone of *X. carbonaria* in the upper part of the middle Productus limestone and that of *Cyclolobus oldhami* considerably higher up, in the upper Productus limestone. Waagen's original specimens of these two species were obtained from the same band in the upper Productus limestone,[1] and hence this zone may not improbably correspond with the zone of *Xenaspis* cf. *carbonaria* and *Cyclolobus* cf. *oldhami* in the Productus shales of Spiti. The lower part of the Productus shales would therefore correspond in part to the lower part of the upper Productus limestone and probably also to part of the middle Productus limestone.

The underlying calcareous sandstone has been correlated by Dr. Noetling with the middle Productus limestone of the Salt Range.[2]

The following table taken from a more comprehensive one prepared by Dr. Noetling[3] shows the correlation adopted by him:—

[1] Pal. Indica, ser. XIII, vol. I, p. 25.
[2] Neues Jahrbuch für Min., etc., vol. XIV, 1901, p. 444.
[3] *Ibid.*, opposite p. 468.

				Salt Range	Spiti
Trias	Scythian (Buntsandstein)	Upper	Upper ceratite limestone	Zone of *Stephanites superbus*	Not yet recognised.
			Ceratite sandstone	„ *Flemingites flemingianus*	"Hedenstræmia beds"
		Middle	Ceratite marl	„ *Koninckites volutus*	
				„ *Prionolobus rotundatus.*	Zone of *Meekoceras lilangense.*
		Lower	Lower ceratite limestone	„ *Celtites* sp.	
Permian	Thuringian (Zechstein)	Upper	Chideru group, or upper Productus limestone	Zone of *Euphemus indicus*	Zone of *Ophiceras tibeticum*
				„ *Medlicottia wynnei*	
				„ *Bellerophon impressus*	Zone of *Otoceras woodwardi*
				„ *Cyclolobus oldhami*	Dark shales with *Cyclolobus oldhami*
				„ *Derbyia hemisphærica*	
				„ *Productus lineatus*	
		Middle	Virgal group, or middle Productus limestone	„ *Xenodiscus carbonarius*	Dark shales with *Xenodiscus carbonarius*
				„ *Lyttonia nobilis*	Calcareous sandstone with *Spirifer musakheylensis*
				„ *Fusulina kattaënsis*	
		Lower	Amb group, or lower Productus limestone	„ *Spirifer marcoui.*	Conglomerate and sandstones

It will be noticed that the calcareous sandstone of Spiti has been correlated with the lower zones of the middle Productus limestone; the fossils obtained from this bed in Spiti are, however, hardly suffi-

ciently numerous or sufficiently characteristic to warrant any exact correlation.

The overlying beds (the Productus shales) have been represented by Dr. Noetling as containing two distinct cephalopod zones in Spiti, *viz.*, a lower with *Xenaspis carbonaria*, and an upper with *Cyclolobus oldhami*. This subdivision is apparently due to some slight misapprehension, for, so far as is known at present, there is one and only one ammonite-bearing zone in the Productus shales, and this is situated about 30 feet below the top. All the ammonites hitherto found occur in this one zone, which consists of a string of concretions, and its total thickness is not more than one foot.

It has already been stated that the Productus shales and calcareous sandstone are found in all permian sections in Spiti and Bashahr, but the underlying beds down to the lowest beds of the carboniferous (or devonian) limestone are very frequently absent, nor are they known to occur in any other part of the Himálayas. In lower Spiti, and again at the head of the Spiti river, they are found in their fullest development, and in both areas the carboniferous limestone and the Fenestella shales have been found. The Fenestella shales are well exposed in the hills behind Losar.

Probable representatives of the Po series in Kashmir.

Judging from the manner in which the younger palæozoic beds thicken out again in upper Spiti, it is probable that they will be found also to the north, in the valley of the upper Chandra river in Lahaul and in Kashmir. In fact, a great area has been mapped by Mr. Lydekker in that area as "Panjál", but from his descriptions of that system, it is possible that it may include a considerable part of the shale and quartzite series now known to be most probably of upper carboniferous age. The slates, quartzites and sandstones described by him,[1] as exposed on the southern side of "the Lingti valley, one of the tributaries of the Tsárap valley" appear to correspond so closely in character with the Po series, that they are possibly merely its northern continuation. Further to the

[1] Memoirs, G. S. I., vol. XXII, p. 171.

east, the series is certainly continuous under the high mesozoic ranges north of the Spiti river between Po and Changrizang, and is seen again in Rupshu, where, however, the rocks have been greatly affected by contact- and dynamo-metamorphism.

Representatives of the carboniferous system in Kashmir.

The lower carboniferous limestones are not known to occur in Kashmir,[1] the only limestones referred by Lydekker to that system being the Zewán beds described originally by Godwin Austen.[2] These beds are now generally regarded as not older than upper carboniferous, and they cannot therefore correspond with those of the Lipak river. It seems possible, however, that lower carboniferous limestones may occur in Kashmir, for certain sections described by Lydekker, in which slates and quartzites are found overlying limestones, distinctly recall the carboniferous beds of lower Spiti; in most cases, however, Lydekker looks upon the slates and quartzites as members of his Panjál system and consequently assumes that the section is inverted, and that the limestone belongs to his "Supra-kuling series." The true relations can only be determined by a careful and detailed survey, but the question is one of great interest, and the probabilities are certainly in favour of the existence of lower carboniferous beds in Kashmir.

The following table shows the subdivisions of the younger palæozoic systems of Spiti and Bashahr:—

[1] Except in Rupshu: see below, p. 93.

[2] Quart. Journ. Geol. Soc., vol. XX, p 383, vol. XXII, p. 29.

			Kanaur (Lipak river), upper and lower Spiti (Losar and Po)	Pin valley, southern and central Spiti
PERMIAN		"Productus shales"	Black shales with *Xenaspis* and *Cyclolobus* above, and *Marginifera himálayensis* below	Black shales with *Xenaspis* and *Cyclolobus* above, and *Marginifera himálayensis* below
			Calcareous sandstone with *Spirifer fasciger*, *Spirifer marcoui*, etc.	Calcareous sandstone with *Spirifer fasciger*, *Spirifer marcoui*, etc.
			Grit, quartzite and conglomerate.	
CARBONIFEROUS	(?) UPPER	"Po series"	Quartzite and shale ("Fenestella shales")	*Unconformity*
	LOWER		Quartzite and shale, with Culm plants	
		"Lipak series"	Limestone and thin bands of shale with *Syringothyris cuspidata*, *Productus cora*, etc.	Grey limestone, with *Syringothyris cuspidata*
(?) DEVONIAN			Shaly limestone, with (?) *Streptorhynchus umbraculum* (?) *Atrypa aspera*	Flaggy limestone and sandstone

CHAPTER V.

MESOZOIC GROUP.

During the summer of 1898 the lower trias of Spiti was examined in detail by the present writer, and large collections of fossils were made: at the same time the upper triassic beds were also examined, but only somewhat cursorily, and collections were made from only a few horizons. In the following year the writer was accompanied by the late Dr. von Krafft, whose extensive knowledge of triassic fossils rendered him specially suited to the study of the great complex of triassic rocks of Spiti, and it was therefore arranged that he should confine his attention chiefly to the mesozoic beds, while the present writer undertook the palæozoic systems. By this arrangement it was hoped that it might be possible to give a comprehensive and fairly detailed account of the stratigraphy of Spiti, but owing to the sudden death of Dr. von Krafft, the whole work has devolved upon the writer, and since it was found impossible at present to devote another season to field work, the following account of the mesozoic systems has been based on the somewhat scattered notes made by him and on the materials left by the late Dr. von Krafft, from which the greater part of the present chapter has been compiled. At the same time the progress reports published by Dr. von Krafft in the Annual Reports[1] of this department have been largely drawn on, and the work must in the main be looked upon as his.

Triassic System.

LOWER TRIAS.

Previous observers.

Although the supposed existence of lower triassic beds in Spiti had been recorded as early as 1865,[2] no section had been described in detail from any part of the

[1] General Report, G. S. I., 1899-1900 and 1900-1901.

[2] C. W. Gümbel: "Ueber das Vorkommen von unteren Triasschichten in Hochasien"; Sitz. k. k. Akad. d. Wiss., 1865.

Himálayas until many years later, when the remarkable discovery by Mr. Griesbach of a complete passage from permian to trias in the mountains of Kumaon and Garhwál completely revolutionised existing ideas on the subject of Himálayan stratigraphy. Stoliczka, too, had previously found, in South Karnág beds that he regarded as of lower triassic age, but he apparently obtained no fossils from them, and he overlooked the fossiliferous horizons at the base of the trias in Spiti. The section described in greatest detail by him is that seen behind Kuling, where, according to his description, the Productus shales are immediately overlain by beds with *Daonella lommeli*.[1] This statement was due to the fact that his observations were made on an imperfect section found low down on the left side of the small stream which runs between Kuling and Kungri. Here the lower trias and muschelkalk have been cut out by a fault, and the section is exactly in accordance with his description, but a little further to the east, on the higher part of the ridge, the whole of the lower trias is found in its normal position.

STOLICZKA.

By Mr. Griesbach the base of the trias was assumed to lie at the top of the Productus shales, which, in all normal sections in Spiti are overlain by a series of thin alternating beds of limestone and shale. The following subdivision of the lower trias will be found in his memoir (Mem., G. S. I., vol. XXIII, p. 220):—

GRIESBACH.

11.	Light-grey limestone; *Ptychites gerardi*, and other muschelkalk forms . . . . . *Brachiopod* limestone	Lower trias.
10.	*Otoceras* beds (passage-beds)	

The beds containing *Otoceras* were regarded by him as either of lower triassic age[2] or as permo-trias passage-beds.[3] Between these and the "Brachiopod limestone" there is a considerable thickness of thin-bedded limestone and shale, containing fossils; no special name

[1] Memoirs, G. S. I., vol. V, p. 345.

[2] Records, G. S. I., vol. XIII, p. 103; Memoirs, G. S. I., vol. XXIII, pp. 174, 177, 219.

[3] Records, G. S. I., vol. XXII, p. 166; Memoirs, G. S. I., vol. XXIII, pp. 68, 219, 223.

was given by him to these beds, but they were recognised as a separate subdivision.[1]

In the following table will be found the subdivision and correlation of the lower trias as adopted in the present memoir:—

Concretionary limestone with shaly partings, with *Ptychites rugifer* *Ceratites thuillieri*, etc.	Upper	Muschelkalk
Shale with *Spiriferina stracheyi* *Spirigera stoliczkai*, etc.	Lower	
Limestone with *Sibirites prahlada* *Ceratites subrobustus*, etc.		
Nodular limestone		Lower Trias
Shale with *Rhynchonella griesbachi*		
Limestone with *Pseudomonotis himaica*		
Limestone and shale with *Hedenstræmia mojsisovicsi* *Flemingites rohilla*, etc.	Hedenstræmia beds	
Limestone with *Meekoceras*. Limestone with *Ophiceras*. Limestone with *Otoceras*.		

[1] Memoirs, G. S. I., vol. XXIII, p. 70.

In 1891, the Otoceras beds (Griesbach) were included by the late Dr. Waagen[1] in the permian system, but were accepted as passage-beds and correlated with the Djulfa beds and with the Chideru and overlying unfossiliferous beds of the Salt Range; in a subsequent paper,[2] however, he placed them in the Scythian series of the triassic system.

"Otoceras beds."

The beds between the top of the Productus shales and the horizon of *Rhynchonella griesbachi* were subsequently divided by Diener[3] into the "Otoceras beds" and "Subrobustus beds," the former name being applied to the lower part of the series. Further detailed study of the numerous sections in Spiti has shown that the genus *Otoceras* is apparently confined to a narrow band of limestone, only a few inches in thickness, occurring at the base of the series, and the lower beds have been found by Dr. Noetling in Niti and by Dr. von Krafft in Spiti to contain three distinct zones, each characterised by the predominance of a single genus of ammonite. The two lower zones have been referred by Dr. Noetling to the permian system.[4]

The three zones are, in descending order,—

(3) *Meekoceras* zone—

Thin, concretionary limestones, alternating with thin layers of shale, and containing large numbers of *Meekoceras* . 3 ft.

The fossils include

Meekoceras varaha, Diener.
" many new species.
Proptychites ammonoides, Waagen.
" *markhami*, Diener.
Clypites n. sp.

(2) *Ophiceras* zone—

Grey limestone . . . . . 1 ft. 5 ins.
full of *Ophiceras sakuntala*, Diener, and containing also
Meekoceras varaha, Diener.
Pseudomonotis griesbachi, Bittner.

(1*a*) Brown, sandy limestone, apparently unfossiliferous . 1 ft. 7 ins.

[1] Pal. Indica, ser. XIII, vol. IV, pt. 2, Table of Strata, opp. p. 238.
[2] Sitzungsber. d. k. Akad. Wien, CIV, pt. 1, 1895, pp. 1278 sqq.
[3] Denkschrift der k. Akad. Wien, Bd. LXII, 1895, pp. 533—608.
[4] Neues Jahrbuch für Min., etc., XIV, 1901, p. 467.

(1) *Otoceras* zone—

Hard, ferruginous limestone	5 ins.
with *Otoceras woodwardi*, Griesbach.	
„ *clivei*. Diener.	
„ n. sp.	

It was at first supposed by Dr. von Krafft that bed No. 2 was that in which *Otoceras* occurred, although no specimens of that genus were found by him in Spiti. It had, however, already been obtained by the present writer from the lowest horizon, and was subsequently found in the same bed by Dr. von Krafft in other parts of the Himálayas. He therefore adopted the above subdivision of Diener's "Otoceras beds." The lowest or Otoceras zone can now be almost certainly correlated with the "main layer of *Otoceras woodwardi*" of Kumaon and Garhwál. From this horizon Professor Diener obtained one specimen of *Medlicottia dalailamæ*, Diener,[1] while from the shales immediately overlying this "main layer" another specimen was collected by Mr. Griesbach. A comparison of these specimens with *Medlicottia wynnei*, Waagen, from the Chideru beds of the Salt Range, led Dr. von Krafft to the conclusion that the two species were identical,[2] and he therefore correlated the Chideru beds with the Otoceras zone of the Himálayas, thereby giving support to Dr. Noetling's opinion as to the permian age of the Otoceras zone. At the same time, it should be noted that Professor Diener refuses to admit the identity of the two forms,[3] and the question cannot, therefore, be considered as beyond dispute.

Otoceras zone.

At the end of the last chapter Dr. Noetling's table of correlations of the Salt Range horizons with those of the Himálayas has been partly reproduced[4]: from this it will be seen that he places the Otoceras zone even lower in the series than did Dr. von Krafft, and correlates the overlying zone (Ophiceras zone) with the zones of *Medlicottia wynnei* and *Euphemus indi-*

Ophiceras zone.

[1] Pal. Indica, ser. XV, vol. II, pt. 1, p. 59.
[2] Centralblatt für Min., etc., No. 9, 1901, p. 275.
[3] *Ibid.*, No. 17, 1901, p. 513.
[4] *Supra*, p. 56.

cus, and the Meekoceras zone with the zone of *Prionolobus rotundatus* and *Celtites* sp. With regard to the Meekoceras zone, Dr. von Krafft stated, in the paper quoted above, that it certainly belonged to the lower trias, while he left the age of the Ophiceras zone doubtful, having no proof of either a permian or a triassic age. On the other hand, Dr. Noetling has correlated the latter zone with the uppermost permian, on account of the supposed absence of the genus *Meekoceras*[1]; but, as will be seen from the list of fossils already given, that genus has been found in the Ophiceras zone in Spiti, and any attempt at correlation on this ground with the zones of *Medlicottia wynnei* and *Euphemus indicus* therefore fails.

Meekoceras zone.

It would perhaps seem unnecessary to discuss this question in such detail in the present memoir, but it has been deemed advisable to indicate as briefly as possible the present state of the discussion, which may be summed up as follows :—

The Meekoceras zone has been unanimously referred to the lower trias: the age of the Ophiceras zone was looked upon as doubtful by Dr. von Krafft, while the reason given by Dr. Noetling for placing it in the permian system is not valid for Spiti; with regard to the Otoceras zone, a strong case in favour of its permian age has been made out by Dr. von Krafft in the supposed identity of *Medlicottia wynnei*, Waagen, with *M. dalailamæ*, Diener. This question of identity or otherwise can be decided only by specialists, and as it still remains a matter of dispute, it has seemed preferable in the present memoir to describe the zone in connexion with the series to which it belongs *lithologically*, leaving its age an open question. As already stated, it was regarded by Mr. Griesbach as a passage-bed between the permian and trias, and until many more sections in the Himálayas have been worked out in detail, it is unlikely that we shall be able to assign it definitely to one system or the other.

Above the Meekoceras zone there is an alternating serie of thin-

[1] *Op. cit.*, p. 466.

bedded limestone and shale, having a total thickness of about 34 feet. This is the equivalent of the greater part of Diener's "Subrobustus beds" of the Kumaon Himálayas. In the present memoir this term will not be employed, for *Ceratites subrobustus*, Mojs., has not been found in these beds in Spiti, but occurs at a considerably higher horizon; the name "Hedenstræmia beds," suggested by Dr. von Krafft, will therefore be substituted.

Hedenstræmia beds.

The lower part of the series consists of a band of hard limestones, weathering brown; it is about 4 feet thick, and contains few fossils, which are badly preserved but appear to include *Flemingites* sp. Owing to the absence of fossils, it is uncertain whether this band should or should not be included in the Hedenstræmia beds. It is overlain by thin-bedded limestone, with narrow partings of shale, having a total thickness of about 30 feet, and containing numerous lower triassic fossils, which include—

Danubites nivalis, Diener.
„ *purusha*, Diener.
„ *kapila*, Diener.
Hedenstræmia mojsisovicsi, Diener.
Flemingites rohilla, Diener.
„ cf. *salya*, Diener.
Aspidites superbus, Waagen.
Koninckites yudisthira, Diener.

The above series constitutes the "Hedenstræmia beds" in the sense in which the term was employed by Dr. von Krafft. Ammonites occur throughout the series, which is overlain by lithologically similar beds of limestone and shale having a thickness of about 6 feet. Two fossiliferous horizons occur in these beds; the lower horizon has yielded large numbers of bivalves, which consist almost entirely of *Pseudomonotis* (? *Avicula*) *himaica*, Bittner, and *Pseudomonotis decidens*, Bittner.

Horizon of *Pseudomonotis himaica.*

The upper horizon, which is a calcareous shale or shaly limestone, occurs 6 feet higher up and contains brachiopods, including *Rhynchonella griesb* Bittner, and *Retzia himaica*, Bittner.

Horizon of *Rhynchonella griesbachi.*

Nodular limestone.

This horizon, which has hitherto been regarded as the base of the muschelkalk, is overlain by a bed, about 60 feet thick, of hard, nodular limestone, containing hardly any fossils, those which occur being usually too badly preserved for determination.

Boundary between lower trias and muschelkalk.

In his paper already quoted Professor Diener states[1] that in addition to the species mentioned above, the beds with *Rhynchonella griesbachi* had yielded also the following forms (determined by the late Dr. A. Bittner[2]):—

Spiriferina stracheyi, Salter.
Retzia n. sp. (= *R. himaica*, Bittner).
Spirigera, n. sp. (= *S. stoliczkai*, Bittner).

Although the band with *Spiriferina stracheyi* is very well developed and highly fossiliferous in all muschelkalk sections in Spiti, yet in spite of most careful search, neither Dr. von Krafft nor the prese writer could find in it any trace of *Rhynchonella griesbachi*, but subsequently the latter species was found by Dr. von Krafft in Kumaon in the bed immediately below the nodular limestone; the two brachiopod-bearing horizons being thus separated from one another by a vertical distance of about 70 feet.

The horizon of *Rhynchonella griesbachi* not having been previously recognised in Spiti, a careful search was made during the last field season, with the result that it was found in the same position as in Kumaon, that is to say, below the nodular limestone. At the same time the true position of the horizon of *Pseudomonotis himaica* was also determined. While collecting from the horizon of *Rhynchonella griesbachi*, the present writer found, both in and above it, several poorly preserved fragments of ammonites, which appeared to resemble lower triassic species; these were submitted to Dr. von Krafft, but they were in most cases too badly preserved to admit of determination. A

[1] Denkschrift. der k. Akad., Wien, LXII, 1895, p. 571.
[2] Pal. Indica, ser. XV, vol. III, pt. 2.

few, however, were determinable: these were derived from two horizons—

(*a*) six inches above the top of the bed with *Rhynchonella griesbachi*; and

(*b*) middle of the nodular limestone, *i.e.*, about 30 feet above the horizon of *Rhynchonella griesbachi*.

The specimens from (*a*) include—

Tirolites n. sp.[1]

(?) *Dinarites* sp. ind.

The first of these forms had hitherto been found only in the lower trias, having been obtained from the Hedenstræmia beds near Muth.

Horizon (*b*) yielded—

Ceratites n. sp., identical with a form previously obtained from the Hedenstræmia beds at Muth; and

Nannites n sp. ind.

With regard to these discoveries it will be advisable to quote Dr. von Krafft's own words, from a letter written by him to the present writer, shortly before his death: "It is clear that the horizon of *Rhynchonella griesbachi*, looked upon by Diener, Griesbach, Bittner and myself as lower muschelkalk, must be included in the lower trias, and so must at least half of the nodular limestone. The genus *Tirolites* is in Europe known from the lower trias only: the species from the base of the nodular limestone is, moreover, identical with a type from the 'Subrobustus beds' (Diener). The occurrence of *Ceratites* n. sp. in the middle of the nodular limestone only corroborates this conclusion. The boundary between the lower trias and the muschelkalk is therefore much more accurately fixed than it was before, and must lie either within the nodular limestone or at the base of the beds with *Spiriferina stracheyi*. The former is, I think, more probable, because I remember having found lower muschelkalk types in the topmost beds of the nodular limestone."

[1] A description of this species, which he named *T. injucundus*, has been left among Dr. von Krafft's descriptions of lower trias ammonites, which it is hoped will be published shortly.

In view of the above, the upper boundary of the lower trias will lie somewhat higher than has hitherto been supposed, and must be taken somewhere above the middle of the nodular limestone. Plate IV represents a section of the lower and middle trias in the hills to the south-east of Muth. A comparison of this figure with that to be found on page 546 of Professor Diener's account of his expedition to the Himálayas in 1892[1] will show that the lithological succession of this part of the trias of Spiti is almost identical with that of Painkhanda, but the interpretation given above of the Spiti sequence differs from that given by Professor Diener for the Shalshal cliff.

The Productus shales, Otoceras beds and Hedenstræmia beds—Diener's "Subrobustus beds" in part—are the same in both sections while his "Subrobustus beds" include the horizon of *Pseudomonotis himaica*, which fossil was first discovered by him in the Shalshal cliff.

His subdivision (4), which he names the "horizon of *Sibirites prahlada*," is said by him to contain also *Rhynchonella griesbachi* and *Spiriferina stracheyi*, but this association of the two last-named brachiopods was considered by Bittner as highly improbable.[2] These doubts were subsequently confirmed by Dr. von Krafft, who had an opportunity of studying Diener's original section on the spot: he found that the section was in every respect similar to those of Spiti, and that there were two brachiopod-bearing horizons, *viz.*, that of *Spiriferina stracheyi* above, and that of *Rhynchonella griesbachi* below, the nodular limestone, nor could he find in the lower horizon any trace of the brachiopods so common in the upper, while the horizon of *Spiriferina stracheyi* was found to correspond in every respect with the same horizon in Spiti. At that time the lower horizon had not been detected in Spiti, and on Dr. von Krafft's suggestion the present writer made a careful search for it and succeeded in finding it at the base of the nodular limestone, in the exact position in which it was found by Dr. von Krafft at the Shalshal cliff; in Spiti, however, it is poorly developed and fossils are scarce, and it had consequently been previously overlooked.

[1] Denkschrift. der k. Akad., Wien, LXII, 1895.
[2] Jahrbuch k. k. Geol. Reichsanstalt, XLVIII, 1899, p. 692.

As already implied, Dr. von Krafft also found the nodular limestone of Spiti represented in the Shalshal section by an exactly similar bed: this is No. 5 of Diener's section, hence his horizons (4) and (5) will correspond respectively with the horizon of *Rhynchonella griesbachi* and the nodular limestone of Spiti.

MIDDLE TRIAS.

As stated above, the upper boundary of the lower trias, which had hitherto been drawn at the base of the horizon of *Rhynchonella griesbachi* must now be placed somewhat higher up, at, or above, the middle of the nodular limestone. At present our knowledge of this bed is so small, and its fossil contents so few and so badly preserved, that no more accurate delimitation is possible.

The following subdivisions constitute the middle trias of Spiti:—

Daonella limestone		Hard, black limestone, with *Daonella lommeli*, Wissm.	145 ft.
Daonella shales		Black, thin-bedded and flaggy limestone, with greyish-black calcareous and earthy shales, containing *Daonella lommeli* and cephalopods	160 ft.
Muschelkalk	Upper	Dark, concretionary limestone, with thin beds of dark shale, containing *Ptychites gerardi*, Blanf.	20 ft.
	Lower	Grey limestone with *Xenaspis* sp. and *Ceratites* aff. *ravana*, Diener	1 ft. 4 ins.
		Grey concretionary limestone . . .	6 ins.
		Grey shaly limestone, with *Spiriferina stracheyi*, Salt.	4 ins.
		Grey limestone	3 ins.
		Hard, dark grey limestone, with *Ceratites subrobustus*, Mojs., and *Sibirites prahlada*, Diener	4 ins.
		Thin-bedded, grey limestone and shale .	3 ft.
		Upper part of nodular limestone	

MUSCHELKALK.

Horizon of *Ceratites subrobustus.*

The nodular limestone is overlain by thin beds of limestone and shale, containing badly preserved cephalopods, none of which have been determined. Above this is a narrow band of limestone, in which are numerous well-preserved fossils. They include—

Ceratites subrobustus, Mojs.
Monophyllites confucii, Diener.
" *pitamaha*, Diener.
Sibirites prahlada, Diener.
Gymnites ugra, Diener.
Danubites kansa, Diener.
Hungarites sp.

This bed has been traced throughout Spiti and Bashahr, but is particularly well seen in the upper Thanam valley and near Tanga Chenmo in the valley of the Gyundi river.

Calcareous shale with *Spiriferina stracheyi.*

A few inches higher up is a band of shaly limestone or calcareous shale, containing the characteristic fossils of the horizon of *Spiriferina stracheyi, viz.*:—

Spiriferina stracheyi, Salter.
Spirigera stolicskai, Bittner.
Terebratula himalayana, Bittner.
Rhynchonella mutabilis, Stol.

The discovery of these two horizons in one and the same section is one of considerable importance, for the cephalopod fauna with *Ceratites subrobustus* contains a large number of species which had hitherto been found only in the detached and isolated blocks (so-called *klippen*) of Chitichun, and were described by Diener,[1] who believed them to be of lower muschelkalk age.

It was at first supposed that the cephalopod and the brachiopod horizons were separate and distinct, but it was subsequently found by Dr. von Krafft that brachiopods occur also with the cephalopods and the two probably constitute one horizon, in the lower part of

[1] Pal. Indica, ser. XV, vol. II, pt. 2, pp. 101--118.

which cephalopods predominate, and in the upper, brachiopods.[1] This single horizon would then correspond to Diener's "horizon of *Sibiritites prahlada*" of the Shalshal cliff, which, however, should be placed above and not, as represented in his section, below the nodular limestone (see Pl. IV).

Above the horizon of *Spiriferina stracheyi* a band of limestone about two feet thick, contains *Xenaspis* sp. and *Ceratites* aff. *ravana*, Diener. This probably forms the highest horizon of the lower muschelkalk; it is overlain by the mass of limestone and shale which constitutes the upper muschelkalk and which contains a very rich fauna, including over 65 species of *Ammonoidea*. Of these, the most important will be found in the following list:—

Boundary between upper and lower muschelkalk.

Upper muschelkalk fossils.

Ceratites voiti, Oppel.
„ *ravana*, Diener.
„ *hidimba*, Diener.
„ *airavata*, Diener
„ *dungara*, Diener
„ *vyasa*, Diener.
„ *thuillieri*, Oppel.
„ *himalayanus*, Blanford.
„ *horridus*, Oppel.
„ sp. ind. aff. *Cer. wetsoni*, Oppel.
„ aff. *trinodosus*, Mojs.
„ aff. *superbus*, Mojs.
„ aff. *abichi*, Mojs.
„ aff. *kamadeva*, Diener.
Japonites (*Danubites*) *dritarashtra*, Diener.
„ n. sp.
Trachyceras aff. *longobardicum*, Mojs.
Acrochordiceras damesi, Noetling.
Isculites hauerinus, Stol.
Joannites aff. *diffissus*, v. Hauer.
Meekoceras khanikoffi, Oppel.
„ aff. *proximum*, Oppel.

[1] Similar beds were subsequently found by Dr. von Krafft in the Bambanag cliff in Painkhanda, where *Spiriferina stracheyi* occurs in the same bed with *Ceratites subrobustus* and *Monophyllites hara*: a full discussion as to the correlation of the trias of Spiti with that of other parts of the Himalayas will be found in Dr. Krafft's paper, which will form part 2 of this volume.

Gymnites jollyanus, Oppel.
„ *kirata*, Diener.
„ *vasantasena*, Diener.
„ *lamarcki*, Oppel.
Buddhaites rama, Diener.
Sturia sansovinii, Mojs.
Proarcestes bicinctus, Mojs.
„ *balfouri*, Mojs.
Hungarites nitiensis, Mojs.
„ n. sp.
Monophyllites sp.
Ptychites rugifer, Oppel.
„ *tibetanus*, Mojs.
„ *mangala*, Diener.
„ *sukra*, Diener.
„ *cognatus*, Oppel.
„ *asura*, Diener.
„ *govinda*, Diener.
„ *impletus*, Diener.
„ *sahadeva*, Diener.
„ *sumitra*, Diener.
„ *gerardi*, Blanf.
„ *everesti*, Oppel.
„ *vidura*, Diener.
„ *drona*, Diener.
„ *cochleatus*, Oppel.
„ *cochleatus var.*, Oppel.
„ *mahendra*, Diener.
„ n. sp. ex. aff. *P. malletianus Stol.*, Diener.

Nautiloidea also occur, including—

Nautilus cf. *griesbachi*, Diener.
„ *spitiensis*, Stol.
Pleuronautilus sp.
Orthoceras cf. *campanile*, Mojs.

Of *Brachiopoda*, *Spirigera hunica*, Bittner, is common.

In addition to the above species, which were determined by Dr. von Krafft, there are numerous new species which still await description.

The earliest collections of muschelkalk fossils from Spiti were made by the brothers Schlagintweit,[1] by Dr. Gerard[2] and by

[1] A. Oppel: "Ueber die ostindische fossilreste, etc.," Pal. Mittheilungen, I, p. 267. C. W. Gümbel: "Ueber das vorkommen von unteren Triasschichten in Hochasien," Sitz. k. k. Akad. d. Wiss, 1865.

[2] See H. F. Blanford, in Journ. As. Soc. Beng., 1863, No. 2, pp. 124—138.

Stoliczka.[1] Subsequently they were considerably augmented by Mr. Griesbach.

From the list given above it will be seen that there is the closest resemblance between the muschelkalk fauna of Spiti and that of the more easterly parts of the Central Himálayas, almost all the species that have been recorded from the latter having now been found in Spiti.

Throughout Spiti and Bashahr, wherever the middle trias is exposed, good sections with muschelkalk fossils can be found, but the most accessible are those of the Pin valley, *viz.*, that behind the village of Muth, and the section near (N.-N.-W. of) Kágá on the left side of the Parahio; it is from the latter locality that the greater part of the recent collections was derived.

An examination of the collections made from the muschelkalk of Spiti in 1898, led Dr. von Krafft to believe that the ladinic stage of Europe, hitherto supposed to be wanting in the Himalayan trias,[2] either existed in Spiti as a separate horizon or was included in the upper muschelkalk. At the same time, the presence of this stage in Spiti was inferred by Dr. Bittner[3] from a specimen of *Daonella lommeli*, Wissm., found among the collections entrusted to him for description. Special attention was therefore devoted to this point, and it was found that the ladinic stage was not only present but was very well developed, and that there was a gradual passage between it and the uppermost muschelkalk, several species of ammonites being common to both stages.

The beds representing the ladinic stage fall into two main subdivisions, the lower of which is chiefly composed of shaly beds (Daonella shales), while the upper consists of hard, dark, splintery limestones (Daonella limestone).

[1] Memoirs, G. S. I., vol. V.

[2] E. von Mojsisovics: Pal. Indica, ser. XV, vol. III, pt. 1, p. 135. C. Diener: Denkschr. d. k. Akad., Wien, 1895, p. 581.

[3] A. Bittner: Pal. Indica, ser. XV, vol. III, pt. 2, p. 38.

Daonella shales.

The lower beds are thin-bedded, flaggy and shaly limestones with earthy shales and bands of hard, dark limestone; the thickness of this subdivision is about 160 feet.

Fossils are common near the base of the series; they include—

Daonella lommeli, Wissm.
„ *indica*, Bittner.
* *Spirigera hunica*, Bittner.
* *Proarcestes bicinctus*, Mojs.
* *Ptychites gerardi*, Blanf.
* *Hungarites nitiensis*, Mojs.
„ aff. *mojsisovicsi*, Bœckh.
* „ n. sp.
Ceratites n. sp. aff. *Cer. himalayanus*, Blanf.
Gymnites ecki, Mojs.
Trachyceras ladinum, Mojs.
„ aff. *archelaus*, Mojs.

Forms common to Daonella shales and upper muschelkalk.

The species marked * have already been recorded from the upper muschelkalk; from the above list it will be seen that they also occur in association with *Gymnites ecki*, *Trachyceras ladinum*, and other forms characteristic of the ladinic stage of Europe.[1] The ladinic age of this subdivision is further confirmed by the presence of *Daonella lommeli*, Wissm. A single specimen of this fossil was found by the late Dr. Bittner among the collections made by Mr. Griesbach near Muth,[2] but it was subsequently found to be very common in the so-called "Daonella beds" throughout Spiti and Bashahr.

Absence of palæontological break in middle trias.

It is evident, therefore, that no palæontological break occurs in Spiti above the upper muschelkalk, but that the passage into the ladinic stage is so gradual that no boundary line can be fixed between the two.

[1] A fuller discussion of this question will be found in the General Report, G. S. I., 1899-1900, pp. 208—213.

[2] The presence of this species in Spiti had been originally recorded by Stoliczka, but owing to its absence from his collections, doubts were cast by Dr. Bittner on the accuracy of his determination (Pal. Indica, ser. XV, vol. III, pt. 2, p. 34).

In all sections the muschelkalk is overlain by a narrow band, 8 to 12 inches thick, of rotten, splintery and shaly limestone which contains large numbers of *Daonella*, and contains also the *Cephalopoda* mentioned above as occurring also in the underlying main mass of the upper muschelkalk Immediately above this are the "Daonella shales," with *D. lommeli*.

Daonella limestone.

The lithological characters of this stage are constant throughout Spiti; it consists, as already stated, of two divisions, a lower, in which shales predominate (the "Daonella shales"), and an upper composed of hard, dark limestone (the "Daonella limestone"). The latter is about 145 feet thick and contains few fossils, with the exception of *Daonella lommeli*, which is common throughout.

Owing to these lithological characters, the middle trias of Spiti can usually be recognised at a glance, for the nodular limestone forms a low but steep cliff, followed by the less abrupt slopes of the muschelkalk, while the soft Daonella shales form a still gentler slope, capped by a sheer cliff, often two hundred feet or more in height, of the black Daonella limestone, with part of the overlying upper trias limestones.

Upper Trias.

It has been seen that the lower and middle trias of Spiti has yielded a large and representative fauna. Unfortunately the same cannot be said of the upper divisions of the system, our knowledge of which is much less complete. This is due to a large extent to paucity of fossils, but also to the fact that the uppermost beds of the trias consist of hard dolomitic limestones, forming steep, often vertical cliffs, in many sections quite inaccessible and in others accessible only to the practised mountaineer. Nevertheless many of the horizons of the upper trias of Europec an be recognised and have yielded, locally, characteristic and well-preserved fossils.

It was formerly supposed by Dr. von Mojsisovics and by Professor Diener, that the muschelkalk of the Himálayas was immediately overlain by beds representing in part the carnic stage of Europe, but, as

already stated, more recent work in 1898 and 1899 had proved that this was not the case in Spiti, but that beds including the ladinic stage were largely developed. Subsequently Dr. von Krafft, when studying the sections of the Kumaon Himálayas, came to the conclusion that the same stage was represented also in the Shalshal cliff, but that the beds including it were much thinner, being only 45 feet thick as against 300 feet in Spiti.[1] In both areas it is overlain by beds containing fossils found in the carnic stage of Europe. In Spiti these beds fall into the following subdivisions :—

Ladinic stage of Europe represented in Painkhanda.

Tropites beds	6. Dolomitic limestone	300 ft.
	5. Dark, splintery limestone, with alternations of grey, shaly limestone and calcareous shale, with *Parajuvavites*, sp.	200 ft.
	4. Nodular limestone and grey shale, with *Clydonautilus griesbachi*, Mojs. *Tropites* cf. *subbullatus*, v. Hauer. „ cf. *discobullatus*, Mojs. Species of *Juvavites* and *Sagenites*.	15 ft.
	3. Dark, splintery limestone, shaly limestone and calcareous shale	400 ft.
Grey shales	2. Soft, pale grey, calcareous shales, with limestone bands : containing brachiopods above and ammonites below	535 ft.
Halobia beds	1. Hard, dark, splintery limestone, with flaggy and shaly bands with *Halobia* sp., and *Arcestes* sp. .	140 ft.

The lowest of the above subdivisions is a continuation of the black Daonella limestone, but owing to the apparent absence of *Daonella lommeli* in the upper beds and to the presence of *Halobiæ* either identical with, or very nearly

Halobia limestone.

[1] General Report, G. S. I., 1900-01, p. 27.

allied to, *Halobia comata*, Bittner, and *H. fascigera*, Bittner, it has been considered advisable to separate the Halobia beds as a distinct subdivision.

Grey beds.

This limestone is overlain by a thick series of soft, grey or pale lavender shales with which thin bands of limestone are intercalated. Almost immediately above the Halobia limestone, the shales contain a band of black concretions which enclose numerous ammonites; the fossils are in most cases fragmentary, and only one species has been completely determined: this is

Joannites cymbiformis, Wulf.,

which has been found at this horizon at several localities, in Spiti and also in the Thanam valley in Bashahr. The remaining fossils include—

Trachyceras cf. *aonoides*, Mojs.
„ n. sp. aff. *ariæ*, Mojs.
Hauerites n. sp.
Drepanites n. sp.
Joannites cf. *cymbiformis*, Mojs.

Only one other fossiliferous horizon has been found in the grey shales; it occurs at about 300 feet above the base, and consists of a grey, shaly limestone, containing large numbers of brachiopods, which include—

Spiriferina shalshalensis, Bittner;
Rhynchonella lankana, Bittner;
Discina sp.;

and several other forms not yet determined. One ammonite (*Distichites* sp) was found by Dr. von Krafft in this bed, while *Megalodon* sp. and other bivalves occur in the upper part of the series.

Brachiopod limestone.

The brachiopod horizon is overlain by grey shales, about 200 feet thick, similar to those below: thin bands of limestone are intercalated with the shales and become more and more numerous in the upper part of the series, till the formation becomes one of limestone, with subordinate bands of shale: this is subdivision (3) in the above list. Fossils are rare, but above Muth and near Lilang the limestone contains at one horizon large numbers of brachiopods and bivalves, which, however, still await determination,

Tropites beds.

A little higher in the series a band of nodular limestone with gray shales—subdivision (4)—contains ammonites chiefly belonging to the genus *Tropites*. The fossils are rare and badly preserved, but the following forms were recognised by Dr. von Krafft :—

Tropites cf. *subbullatus*, v. Hauer.
„ cf. *discobullatus*, Mojs.
„ cf. *fusobullatus*, Mojs.
„ cf. *torquillus*, Mojs.
Juvavites aff. *bacchus*, Mojs.
„ sp. ind cf. *J. bacchus*, Mojs.
Sagenites sp. aff. *erinaceus*, Dittmar.
„ n. sp. aff. *herbichi*, Mojs.
Sandlingites n. sp.
Sirenites n. sp.
(?) *Heraclites* sp.
Clydonautilus griesbachi, Mojs.
Nautilus sp.

This horizon presumably corresponds to the "Tropites limestone" of Kálápani, which is, according to von Mojsisovics, the equivalent of the "zone of *Tropites subbullatus*" of the Mediterranean Province.[1]

The nodular limestone with *Tropites* is overlain by a band of dark, splintery limestone about 200 feet thick, with beds of calcareous shale; it has yielded few fossils, but some specimens of *Parajuvavites* n. sp. were found by Dr. von Krafft at about 70 feet above the Tropites horizon. One specimen of the same species was found loose on the Tropites beds, and as Dr. von Krafft considered it improbable that under the existing circumstances it could have rolled down from a higher horizon, he assumed that it belonged to the horizon at which it was found and consequently included the upper beds, in which the species occurs, in the Tropites beds.

Dolomite.

The age of the next overlying bed—(6) the dolomitic limestone—is doubtful, it having yielded few fossils, and those very badly preserved and fragmentary;

[1] Pal. Indica, ser. XV, vol. III, pt. 1, pp. 154, 155.

among them, however, are some bivalves which were determined by the late Dr. A. Bittner as—

Lima cf. *austriaca*, Bittner.;
Daonella cf. *styriaca*, Mojs.; and
Halobia cf. *superba*, Mojs.

In Europe, *Lima austriaca* occurs in the Opponitz limestone and *Daonella styriaca* and *Halobia superba* in the carnic beds of Aussee.[1]

The following sequence is found in Spiti above the Tropites beds:—

5. Black, splintery and earthy limestone and dolomite; with
Megalodon ladakhensis, Bittner.
Dicerocardium himalayense, Stol.
Lima cumaunica, Bittner.
„ *serraticosta*, Bittner.
(?) *Spirigera noetlingi*, Bittner.

4. White and brown quartzite, with black shales and grey limestone; with 300 ft.
Spirigera n. sp.
Aulacothyris joharensis, Bittner.
Lima cumaunica, Bittner.
Spiriferina griesbachi, Bittner.

3. Brown-weathering shale (calcareous and micaceous) and shaly limestone, with some sandstone; with 300 ft.
Spiriferina griesbachi, Bittner.
Rhynchonella bambanagensis. Bittner.
Spirigera dieneri, Bittner.
Aulacothyris joharensis, Bittner.
Monotis salinaria, Bronn.
Anodontophora griesbachi, Bittner.
Distichites n. sp.

2. Coral limestone; with 100 ft.
Spiriferina griesbachi, Bittner.
Rhynchonella bambanagensis, Bittner.

1. Brown-weathering shale, with shaly limestone and sandstone; with 500 ft.
Paratibetites cf. *tornquisti*, Mojs.
Juvavites, cf. *ehrlichi*, Mojs.
Hauerites n. sp. ind.

Above the dolomitic limestone a rapid change takes place in the lithological character of the beds. The compact limestones give place

[1] E. von Mojsisovics: Abhandl. k. . Geol. Reichsanstalt, Wien, Bd. VII, (1894), Heft. 2, pp. 10, 30.

to calcareous shales and shaly limestones, and, with the exception of the bed of coral limestone in the lower part of the series, the rocks consist almost entirely of shales with intercalated bands of sandstone; in fact the series consists broadly of two thick beds of calcareous shale or very shaly limestone, separated by the massive coral limestone and overlain by brown and white quartzites; this group is thus easily recognised on the mountain sides, even at considerable distances.

The lower part of the first shaly series (1) is composed of sandy limestones, passing up into sandstones and calcareous shales which contain, in addition to numerous indeterminate plant remains, a few brachiopods and bivalves with fragments of ammonites, including—

Hauerites sp.
Hauerites (?) n. f. ind., Mojs.[1] and
Paratibetites cf. *ternquisti*, Mojs.

The bivalves include—

Mysidioptera sp.
Avicula sp.
Modiola sp.
Anodontophora griesbachi, Bittner.

This horizon was correlated by Dr. von Krafft with the "Hauerites beds" (Diener) of the more easterly sections of the Himálayas.

Juvavites beds.

The overlying shales contain large numbers of ammonites; they are to a great extent fragmentary, but most of their important characters can still be recognised. By far the commonest genus is *Juvavites*, of which a few forms belong to the groups of "intermittentes" and "scissi," but the great majority approach the "continui" (Mojsisovics). Other forms represented are

Paratibetites ternquisti, Mojs.
Tibetites cf. *ryalli*, Mojs.
Anatibetites n. sp. aff. *kelvini*, Mojs.
Clionites aff. *hughesi*, Mojs.
Dittmarites n. sp.
Pinacoceras sp.
Phylloceras sp. ind.
Pleuronautilus aff. *tibeticus*, Mojs.

[1] Pal. Indica, ser. XV, vol. III, pt. 1, p. 88.

A few bivalves also occur in the shales; they belong to the genus *Halobia*, and closely resemble *H. fascigera*, Bittner.

It is probable that these "Juvavites shales" correspond to the "Halorites beds" (Diener), from which they differ, however, in the apparent absence of both *Halorites* and *Parajuvavites*, neither of which genera has been found at this horizon in Spiti.

Coral limestone.

The shales are overlain by a massive, grey—at times white and dolomitic—limestone, chiefly composed of corals. It forms a very characteristic horizon throughout Spiti and Rupshu, but has not been recognised in Kumaon or in Garhwál. The commonest fossil is a coral resembling *Lithodendron*, the presence of which led Mr. Griesbach to regard the limestone as of rhætic age.[1] A few gastropods were found in this bed in Rupshu, and brachiopods in Spiti; the latter are rare, but include—

Spiriferina griesbachi, Bittner; and
(?) *Rhynchonella bambanagensis*, Bittner.

Consequently Dr. von Krafft believed that this limestone represented the "beds with *Spiriferina griesbachi*" of the Painkhanda sections.

Monotis shales.

The coral limestone is overlain by arenaceous limestones and sandstones, passing up into a series of calcareous shale, which in lithological characters strongly resembles the "Juvavites beds." This subdivision, the thickness of which is about 300 feet, contains an interesting fauna, composed almost entirely of bivalves and brachiopods, which occur chiefly in the upper part of the series: they include—

Monotis salinaria, Bronn.
Anodontophora griesbachi, Bittner.
Spiriferina griesbachi, Bittner.
Rhynchonella bambanagensis, Bittner.
Aulacothyris joharensis, Bittner.
Spirigera dieneri, Bittner.

Monotis salinaria, which has been found in almost all sections of these beds in Spiti, occurs in a band which varies from 6 to 8 inches in width and lies at about 100 feet below the top of the series.

[1] Memoirs, G. S. I., vol. XXIII, p. 220.

From 30 to 50 feet higher up the shales contain large numbers of *Spiriferina griesbachi* and *Aulacothyris joharensis*. A very good section is seen in the valley of the Lungtsé stream (Pl. V) which joins the Spiti river between Máni and the Pin valley. The same beds are also seen about 4 miles west of Po, on the road to Dankhar, where they have been brought down by a fault, and again near Sopona E. G., on the path leading to the Mánirang Pass. This is no doubt the outcrop from which specimens of *Spiriferina griesbachi* were collected by Mr. Griesbach.[1] The only ammonite which has been obtained from these beds is *Distichites* n. sp., of which only fragments were found.

In spite of the apparent absence of *Sagenites*, this horizon was provisionally correlated with Diener's "Sagenites beds" of Painkhanda; this correlation was subsequently found by Dr. von Krafft to be correct, for, at the Bambanag cliff in Painkhanda, the "Sagenites beds" are overlain by a quartzite series identical, both lithologically and faunistically, with that which occurs immediately above the Monotis shales in Spiti.

Upper triassic quartzite series.

The quartzite series forms one of the most constant and characteristic horizons of the upper trias of Spiti, and consists of white and brown quartzites, with subordinate bands of limestone. In most sections the quartzite can be seen at a distance of several miles, forming a thin, white band, which stands out among the darker brown and grey beds in the high cliffs of the upper trias. With the quartzites are intercalated limestones and bands of shale, the whole series having a thickness of about 300 feet. Fossils occur in most of the beds, and include—

Spiriferina griesbachi, Bittner.
Aulacothyris joharensis, Bittner.

[1] Pal. Indica, ser. XV, vol. III, pt. 2, p. 53.
Stoliczka's "*Spiriferina tibetica*," which he obtained from near Kibber and which he supposed to be of carboniferous age, almost certainly came from the same horizon which is exposed on the path from Kibber to the Parang Là—Stoliczka's original route. No carboniferous beds are found within many miles of Kibber, *ibid.*, p. 53.

Lima serraticosta, Bittner.
Megalodon ladakhensis, Bittner.
(?) *Dicerocardium*, sp.
Spirigera n. sp.

Megalodon limestone.

The quartzite series is overlain by a mass of dark grey, often dolomitic, limestone, having a thickness of about 2,300 feet. This must include representatives of the European Dachsteinkalk, lias and middle jurassic. Fossils are very rare and badly preserved, but at 50 feet above the quartzite a band of grey limestone, about 20 feet thick, contains immense numbers of *Megalodon ladakhensis*, Bittner, and *Dicerocardium himalayense*, Stol. Where the rock has been polished by the action of running water or moving ice, it has a most striking appearance, for the sections of the two bivalves, being preserved in white calcite, stand out clearly in fantastic patterns from the dark grey matrix (see Pl. XV, fig. 1). This is the characteristic horizon of Stoliczka's "Párá limestone,"[1] blocks of which are very common throughout the upper Párá valley between the Parang Là and Rupshu.

Other fossiliferous horizons.

About 200 feet higher up the massive limestone has yielded one brachiopod and two bivalves, *viz.*—

Spirigera noetlingi, Bittner;
Lima cumaunica, Bittner; and
Lima serraticosta, Bittner.

(?) Oolite.

In addition to these, gastropods and bivalves have been found at about 400 feet above the quartzite series, and a species of *Spiriferina* closely resembling *S. obtusa*, Oppel, about 400 feet higher still, while at about 370 feet below the top of the limestone mass, Dr. von Krafft found an ammonite very nearly allied to, if not identical with, *Stephanoceras coronatum*, Brug.; the horizon at which this fossil occurs may therefore represent the middle oolite, and since there is no trace of unconformity in this great limestone series anywhere in Spiti, the beds

[1] Memoirs, G. S. I., vol. V, p. 124.

lying between the quartzite series and the horizon of *Stephanoceras coronatum* must include the uppermost trias, rhætic and lias. In the present state of our knowledge of these beds it is impossible to attempt any more detailed subdivision.

Jurassic limestone.

The highest beds of the limestone, immediately underlying the Spiti shales, represent the upper part of Stoliczka's "lower Tagling limestone," which he referred to the lias. Fossils are numerous, consisting chiefly of belemnites, bivalves and gastropods. The recent collections have not yet been worked out, but in view of the fact that the limestone underlies, with perfect conformity, the Spiti shales, which have been proved by Uhlig to be of uppermost jurassic age, there is *primâ facie* evidence for referring it to the upper jurassic and possibly upper part of the middle jurassic.

UPPER JURASSIC.

Spiti shales.

The Spiti shales are too well known to require more than passing mention; they have been fully described by Stoliczka who examined them in their typical locality, in the neighbourhood of Kibber, Langja and Giumal, where they form rolling downs, capping the high limestone cliffs on the left side of the Spiti river. The specimens collected from the shales are now in the hands of Professor Uhlig by whom they are being described; a portion of his manuscript has already reached India, and from this it appears that several of the species of ammonites show a tithonian and lower neocomian facies, and the Spiti shales must therefore be regarded as uppermost jurassic, and possibly in part younger.

In addition to Stoliczka's original "jurassic ellipse,"[1] Spiti shales also occur along the higher ridges on the right side of the Spiti river and form a narrow strip running above Máni, over the saddle of the Mánirang, and on into Bashahr.

CRETACEOUS.

Giumal sandstone.

At Giumal, Kibber and Chikkim the Spiti shales are overlain, with interstratification, by hard, yellow and brown sandstones and quartzites, which constitute Stoliczka's "Giumal sandstone," which was referred by him to the upper jurassic. Fossils are fairly common in the lower beds, many bivalves —usually, however, badly preserved—occurring near Giumal and Chikkim, while casts of *Stephanoceras* and *Perisphinctes* were found near Kibber and Chikkim. These sandstones are undoubtedly of cretaceous age.

Chikkim limestone and Chikkim shales.

The highest member of the stratigraphical series of Spiti consists of a bed of grey or whitish limestone, about 100 feet thick, overlain by soft, grey, calcareous shales. These beds form a synclinal on the summit of Chikkim "station," behind the village of the same name, and are found also in the upper reaches of the Lingti river, above Lilang. Fossils are very rare and appear to be confined to the limestone, which has yielded one belemnite, fragments of *Rudistes* and *Foraminifera*, including the genera *Cristellaria*, *Dentalina* and *Haplophragmium*. With the exception of the belemnite, all these fossils were found also by Stoliczka, who therefore referred the limestone to the cretaceous system. The overlying shales are greatly folded and their thickness cannot be determined, but it appears to be about 150 feet: in spite of careful search, no trace of fossils has been found in them.

STOLICZKA'S nomenclature.

The first systematic account of the mesozoic rocks of Spiti was given by Stoliczka, who subdivided the whole group into the following series:—

Chikkim shales	*Cretaceous.*
Chikkim limestone	
Giumal sandstone	*Jurassic.*
Spiti shales	
Tagling (upper)	*Lias.*
Tagling (lower)	
Párá limestone	*Rhætic.*
Lilang limestone	*Trias.*

The four highest of these represent well-defined lithological units each of which, with the exception of the Chikkim shales, has yielded fossils and can be referred with a fair degree of certainty to its European equivalent; for this reason, and also since the same terminology has been employed throughout the Himálayas, Stoliczka's nomenclature has been retained. It has, however, been found necessary to discard the names given by him to the lower members of the group.

The "Lilang limestone" included, according to Stoliczka, the whole of the trias then known in Spiti, that is to say, the beds included between the base of the muschelkalk and the base of the rhætic. It was subsequently found by Mr Griesbach that the lower trias was well represented, while during the last few years it has been proved that much of Stoliczka's rhætic belongs in reality to the upper trias; and since most of the fossiliferous horizons of the trias of Spiti can now be referred to their European equivalents, the retention of the term "Lilang limestone" would be both superfluous and confusing.

For similar reasons the term "Párá limestone" has also been discarded, for it was supposed by Stoliczka to represent the rhætic stage, but as no horizons have yet been found in Spiti which can be definitely referred to that stage, while the "Párá limestone" includes both upper trias and lias, the term ceases to have any significance, for it represents neither a stratigraphical nor yet a lithological unit, both its upper and lower boundaries being undefined.

In the case of the "Tagling limestone," the same difficulty arises. Stoliczka includes in that series a mass of limestone, 2,000 feet thick, underlying the Spiti shales. This must, therefore, include both the middle and lower jurassic, and probably also the rhætic, should this stage be represented in Spiti. It was divided by Stoliczka into two groups, an upper and a lower, the former of which presented the curious anomaly of a formation occurring in only two localities, between the "lower Tagling limestone" and the Spiti shales, which he stated at the same time to be conformable to one another. A recent examination of the "upper Tagling limestone" in one of these localities—the Parang

Là—has proved that it is in reality a part of the "lower Tagling limestone" which has been brought into its present position by an overfold.

A great advance was made in our knowledge of the Spiti trias by the work of Mr. Griesbach, who found that not only was the lower trias well developed, but that the whole series of sedimentary beds from permian to jurassic was very similar to that of Kumaon and Garhwál, and he was then enabled to correlate the trias of those districts with that of Spiti. The surveys carried on during the last few years have tended chiefly to confirm and amplify his conclusions, especially with regard to the lower and middle trias, some small modification only being necessary in regard to the upper parts of that system.

CORRELATION OF THE MESOZOIC BEDS OF SPITI WITH THOSE OF OTHER PARTS OF THE HIMÁLAYAS.

With Kumaon and Garhwál.

The work of Mr. Griesbach and of Professor Diener in Garhwál and Kumaon and of Mr. Griesbach in Spiti, renders it now a comparatively easy task to correlate, with a fair approach to accuracy, the mesozoic beds of these two areas. This had been undertaken by the late Dr. von Krafft, whose paper on the subject will form part 2 of this volume: no further details need therefore be given here.

With Kashmir.

With that part of the Himálayas which lies to the north-west of Spiti, correlation is, unfortunately, almost impossible, for, with the exception of parts of Southern Rupshu, which were examined by the present writer in 1899 and 1901, the Kashmir State has not been surveyed in any detail, Mr. Lydekker's memoir on the "Geology of Kashmir," the work of Godwin Austen, and observations by Dr. Stoliczka along the route to Yarkand, being almost the only sources of information available.

Owing to the great extent of the area surveyed by Mr. Lydekker, his work was necessarily carried out on broad lines only; he included all the mesozoic systems, with the younger palæozoic, in his "Zánskár system," which comprised Stoliczka's Kuling series, Lilang limestone,

Párá limestone, Tagling limestone, Spiti shales, Giumal sandstone and Chikkim limestone and shales, while he employed the term "supra-Kuling series" for the whole of the triassic and jurassic systems. Hence no attempt can be made to correlate the beds of Kashmir generally with those of Spiti, until the stratigraphy of the former area has been worked out in much greater detail. At present we know merely that muschelkalk and upper triassic beds, apparently similar to those of Spiti, have been found at a few localities,—Sonamarg, Vihi, and Gurez,—and it is probable that lower trias and other subdivisions of the mesozoic group will be found to exist.[1]

Of the areas to the north-west and north of Kashmir, our knowledge is equally scanty, but *Monotis salinaria* was found by Stoliczka near Aktash on the Pamir, in a rock which appears to be lithologically identical with that in which the same fossil occurs in Spiti.[2]

CORRELATION WITH THE TRIAS OF EUROPE.

It has been seen that the mesozoic beds of Spiti afford an unbroken series of deposits from lowermost trias to cretaceous, and since many of the characteristic species of the trias of Europe occur also in Spiti, it is possible to recognise many of the stages into which the European sequence has been divided; we thus find representatives of the muschelkalk, ladinic, carnic, and juvavic stages. In such a complete series, however, where individual sections frequently exhibit an unbroken sequence, bed upon bed, from one end of the trias to the other, without a trace of unconformity or gap of any kind, it is natural that horizons should be found which are, so far as we know, not represented in Europe: thus the small band of limestone lying upon the uppermost bed of the muschelkalk contains forms common both to

[1] Since the above was written, lower triassic fossils have been found by Dr. Noetling in Kashmir.

[2] In this connection, it is interesting to note that this very characteristic species has recently been found by Mr. Vredenburg in an extensive system of shales and shaly limestones in the Zhob valley in Baluchistán. See General Report, G. S. I., 1901-1902, p. 31.

that stage and to the ladinic, thus constituting a passage-bed from the one to the other. More detailed work among the upper triassic rocks will also, in all probability, reveal similar gradations between the other stages. It would therefore seem unreasonable to attempt to draw imaginary lines which should represent hard-and-fast boundaries between any two stages; we can merely indicate certain beds of the Himalayan sequence which include the representatives of the smaller European subdivisions. The complete sequence of the mesozoic beds of Spiti will be found in the annexed table, in which, however, no attempt has been made to fix the limits of the corresponding stages of Europe.

CHAPTER VI.

RUPSHU.

With the exception of the local peculiarities due to the unconformities between the cambrian and silurian, and carboniferous and permian systems, respectively, and which have already been noticed in the previous chapters, the characters of the stratigraphical systems of Spiti and Bashahr are so constant that detailed descriptions of a number of individual sections would be superfluous. Further to the north, however, in Rupshu, the beds have been so greatly altered both by dynamo- and contact-metamorphism, that their relations to the Spiti systems can be traced only with great difficulty.

Routes from Spiti to Rupshu.

The valley of the Spiti river is bounded on the north by a chain of snow-clad peaks and ridges, which constitute the eastern extension of the Baralachar Range. From Spiti, three routes lead through this range to Rupshu—

(1) *viâ* the Tagling Là and upper Párá valley;

(2) *viâ* the Parang Là and upper Párá valley;

these two routes converge at about 15 miles below the Parang Là;

(3) from lower Spiti, *viâ* Kurig and Kharak in Western Tibet (To-Tzo), along the lower Párá valley, to Chumar and Lám Tso.

By taking the third route, the present writer was enabled to trace out the connection of the beds of the one area with those of the other, and it has now become possible to refer the metamorphic rocks of Rupshu to their comparatively unaltered representatives in Spiti.

Triassic beds in ranges between Spiti and Rupshu.

The high ranges between Spiti and Rupshu are composed chiefly of rocks of mesozoic age, amongst which the upper triassic coral limestone is a most conspicuous and useful horizon. In many cases, especially in Rupshu, it has been converted by metamorphism into a white dolomite, but still retains its numerous corals. Below this

horizon, all traces of fossils have as a rule been obliterated and the greater part of Rupshu consists, as stated by Stoliczka, of metamorphic schists, to which, however, he did not attempt to assign any definite age. The same rocks were subsequently classed by Lydekker among his "metamorphic Panjáls and archæan." The upper part of this series is well-exposed in the Pánkpo, Párá and Chepzi valleys, where it consists of crushed limestones, slates and calc-schists. Amongst these, representatives of the middle and lower trias and permian can be traced with a great degree of certainty, and correlations based at first on lithological grounds were subsequently confirmed by the discovery of fossils, badly crushed but still recognisable; they are, however, very rare, and have been found only in two localities, in the Pánkpo river, near Kiangshisa, and in the Párá river, near Sitang Gongma. At the former locality *Daonella indica* was found in black calcareous slates, which evidently represent the ladinic stage of Spiti, and in the Párá river the Productus shales were recognised near Sitang Gongma, where they are represented by dark slates containing the characteristic fossils. The Productus shales are underlain by calcareous schists and crushed limestones, which locally contain immense numbers of crinoid stems, and which presumably represent the calcareous beds which underlie the Productus shales in Spiti. They pass down into crushed grits and conglomerates, which clearly represent the permian conglomerates seen near Po. They are very well exposed in the Pánkpo river and also in the valley of the Chepzi stream, and can be traced along the hills on either side of the Párá river near Chepzi. Below these a series of slates and metamorphic schists occupies the greater part of Rupshu between the Pánkpo river and Narbo Sumdo on the one side and the range separating Rupshu from Hánle on the other. To the south of this range, near the Shálshál Pass and at Shálshál Dengo E. G., the schists are underlain by white and dark-grey crystalline limestones, with interbedded white quartzites, which most probably represent the carboniferous beds of the Lipak river.

Effects of metamorphism.

Representatives of palæozoic systems.

Between Narbo Sumdo and the northern end of Tso Moriri the whole of this palæozoic series can be traced, the calcareous schists, conglomerates and quartzites of the permian being underlain by the altered representatives of the rest of the Po series of Spiti. A little to the south of Korzok, the siliceous beds are underlain by calc-schists and crystalline limestone, as already recorded by Mr. Oldham.[1] From Korzok a small ridge runs to the northern end of the lake; this ridge consists of calc-schist and crystalline limestone with some bands of white quartzite, the whole similar, except in the somewhat smaller thickness of the quartzite, to the section seen at Shálshál Dengo. These beds have, therefore, been referred also to the carboniferous, but it is possible that they may be also partly silurian.

The limestones and quartzites are underlain by slates and schists which gradually become garnetiferous, then felspathic, and pass down into the so-called "Tso Moriri gneiss."

Tso Moriri gneiss.

This rock was cursorily examined by the present writer in 1899, and on account of its apparent position among the palæozoic beds it was suggested[2] that it might possibly be a highly metamorphosed representative of the lower silurian quartzite of Spiti. Subsequent determination of the microscopic and chemical characters of the rock, however, showed that there was no evidence in favour of regarding it as primarily of sedimentary origin.

As already stated by Oldham (*loc. cit.*), it forms an apparently well-bedded series, with foliation parallel to bedding, the beds being about two feet thick. In mineralogical composition, it is chiefly an *augen* gneiss, with large "eyes" of felspar. Most of the beds are composed of a quartz-felspar-mica rock, with rods of schörl on the foliation planes. The quartz frequently occurs as a mosaic of small grains. The felspar is chiefly orthoclase and microcline with a little plagioclase, while the mica is a pale, often colourless

[1] Records, G. S. I., vol. XXI, p. 153.
[2] General Report, G. S. I., 1899-1900, p. 197.

and silvery, magnesia mica. In hand specimens it resembles muscovite, but under the microscope appears to be perfectly uniaxial, while chemical analysis shows it to contain a large amount of magnesia: it must therefore be classed under biotite.

With this gneiss are associated bands of white quartz-felspar-muscovite rock, containing no biotite, but with a considerable amount of plagioclase and some schörl. Low down in the series, near Shakshang E. G., fine-grained quartz-biotite schist is found interbanded with the gneiss. It is composed of large quantities of dark brown biotite and finely granular quartz; with it occur also bands of a similar rock, but considerable quantities of zoisite and calcite are added to the other constituents; these two schists have many of the characters of altered sedimentary rocks.

Intrusive biotite granite.

Running through the above series, in bands usually parallel to, but occasionally crossing, their foliation, is another quartz-felspar-biotite rock, foliated and gneissose, but containing biotite in irregular blotches and not in layers as in the "Tso Moriri gneiss." It has hitherto been included with the latter rock, but is almost certainly younger and intrusive in it. The same rock occurs again at Ooti E. G., about 40 miles further to the south-west, where it forms a broad, apparently gneissose, band in the middle of the metamorphic schists which represent the carboniferous and permian beds of Spiti. No signs of the *augen* gneiss of Tso Moriri are to be seen at Ooti. The true origin of this rock can only be ascertained by much more detailed work than has hitherto been possible, and must for the present remain doubtful, but the evidence so far obtained tends to show that it is a foliated biotite granite; whether it is identical or not with the common biotite granite of Rupshu is also uncertain, but it is much more foliated and may belong to an older series of intrusions.

Age and origin of Tso Moriri gneiss.

Even more doubtful is the age and origin of the Tso Moriri gneiss; by Lydekker it was regarded as archæan, but its position, underlying rocks which are not older than silurian, and the gradual lithological passage from the

lowest undoubtedly sedimentary rocks into the gneiss, show that it must either represent an altered sedimentary series, which would then probably be the lower silurian quartzite, or be an old intrusive rock, in which case the gneissose beds between it and the sedimentaries would represent a contact zone.

The composition of a typical specimen of the *augen* gneiss is as follows:—

SiO_2	75·09	per cent
Al_2O_3, Fe_2O_3	18·97	„
CaO	·90	„
MgO	·54	„
K_2O	3·8	„
Na_2O	2·1	„
H_2O	·39	„
	101·79	
Specific gravity	2·65	

This, it will be seen, is the composition of a true granite, and it is not improbable that the so-called gneiss is in reality only the remains of an old crushed-out granite laccolite. A very similar rock is found in the Chandra valley, on the road from Spiti to Kulu; but in this case it is undoubtedly a foliated granite.

The final decision of this question must be left till opportunities arise for a detailed survey of this part of Ládákh; it is probable that an examination of the area lying to the north-west of Tso Moriri would throw some light on the relations of the *augen* gneiss to the sedimentary rocks as well as to the Rupshu granite.

Igneous rocks, both acid and basic, are common throughout Southern Rupshu; a few of these will be dealt with in the following chapter.

CHAPTER VII.

IGNEOUS ROCKS.

The high ranges bordering Spiti on the south, west and east are as has already been stated, composed chiefly of granite ; basic intrusions occur among the palæozoic beds of lower Spiti and Bashahr and in the valleys of the Parahio and Pin rivers.

Granite.

Biotite granite.

The commonest form of this rock is a biotite granite, ranging from a fresh rock of medium grain to a foliated gneissose variety with large porphyritic felspars. In the Sutlej valley, near Asrang and Jangi, numerous masses occur in the altered cambrian slates. The rock is here very pure and free from accessory minerals, consisting mainly of quartz, orthoclase and biotite, with a little muscovite and plagioclase.

Pegmatite.

Associated with the biotite granite in the Sutlej valley, in the Chandra valley, and in the ranges between Kulu and Spiti, are numerous veins of albite granite, containing large quantities of schörl, muscovite, beryl and, locally, garnet and kyanite. Both these types have been previously described by General McMahon and other observers and no further details need be given in the present memoir.

Rupshu granite.

The Rupshu granite is very similar in general characters to that of the Sutlej and Chandra valleys, being a biotite granite with few accessory minerals; it differs slightly, however, in containing—as at Dongan Le, where it is accompanied by eurite—a considerable amount of blue quartz. In spite of this difference it is almost certainly merely an offshoot of the Sutlej valley *massif*, for it can be traced up to the southern boundary of Rupshu and can be seen running through the high range which borders the eastern side of the Párá river above Ākse and Kharak in Western Tibet, and, were it possible to follow it through that country, it would probably be

found to be practically continuous with the intrusive masses found below Kurig on the lower Párá river.

Age of granite.

In Spiti the granite is found intrusive only in the oldest palæozoic beds, but at Lio in Kanaur silurian limestones are penetrated by numerous veins which have altered the sedimentary rocks, the chief product of alteration being wollastonite, which occurs in great quantity about one mile above Lio on the right bank of the Spiti river.

In Rupshu the granite is intruded into the carboniferous and permian schists, while in Western Tibet it would appear to occur in the triassic limestones; in the latter case it was only seen from a distance, and the correctness of the observation cannot therefore be vouched for.

So far, therefore, as concerns the area dealt with in the present memoir it is only possible to assert that the age of the granite is post-carboniferous or possibly post-permian.

Pre-permian granite.

In this connection it is interesting to note that a pebble of biotite granite was found in the permian conglomerate on the left bank of the Spiti river below Dankhar which proves that a pre-permian granite must have existed in the area from which the materials forming these conglomerates were derived, that is to say, to the south and south-west of the Spiti valley.

Basic rocks.

Basic rocks, chiefly of doleritic type, occur at several localities in Spiti and Kanaur. They are in all cases intrusive, and no signs of contemporaneous or interbedded ashes or lavas have been found.

Localities.

The localities at which intrusions have been noticed are: Depsá E. G., in the valley of the Parahio; Muth in the Pin valley; Po, Lari, and opposite Sumrá in the valley of the Spiti river; on the Shalkar (or Sumrá) Pass between Sumrá and Shalkar, and at Ná between Shalkar and Lio.

Depsá: augite-norite.

The Depsá rock was probably originally an augite-norite, but has undergone much alteration. It consists of lath-shaped plagioclase, greatly decomposed

augite, enstatite and ilmenite, all of which are accompanied by secondary decomposition products, including green hornblende and serpentine after augite, bastite after enstatite, leucoxene and some sphene after ilmenite. The rock is intrusive in the cambrian slates and quartzites.

Po: dolerite.

About ¾ mile to the north-east of Po, on the road to Thábo, a broad basic dyke cuts through the shales and quartzites of the Po series. The rock is composed of plagioclase, near labradorite, a pale green, slightly pleochroic augite, apatite and ilmenite, with various secondary minerals, including chlorite, calcite and leucoxene. A very similar rock—which, however, contains also epidote—forms a dyke in the hills opposite Sumrá, and is seen again on the Sumrá Lá, while near Ná numerous dykes of decomposed plagioclase-hornblende rock, with much chlorite, cut through the carboniferous beds. The dykes of Po, Sumrá and Ná are probably all offshoots from one matrix and differ merely in degree of alteration.

Actinolite schist near Lari.

In the Yituitse stream, between Sumrá and Lari, a dyke—in part a sheet—of actinolite-chlorite rock with decomposed felspar, some ilmenite, and sphene, probably represents a still further stage of decomposition.

The above rocks have no characters of sufficient interest to demand more detailed description; it is quite certain, however, that they are intrusive, and not, as Stoliczka thought, contemporaneous flows interbedded with the slates and quartzites. It is necessary to emphasize this point, for the supposed existence of interbedded traps in beds regarded by Stoliczka as silurian has been employed as a means of correlating the volcanic beds of Kashmir and other areas with the palæozoic systems of Spiti.

Basic rocks of Rupshu.

The traverse of Southern Rupshu made by the present writer was too rapid to permit of any detailed examination of the countless basic intrusions found throughout that district. At present it is only possible to say that there appear to be two distinct series of basic rocks—a

garnetiferous and a non-garnetiferous; of these the former appears to be much the older, and has been found only in the "Tso Moriri gneiss," at numerous localities near the northern end of that lake, near Tso Kyagar, and between Shakshang and Púga. All the intrusions are similar to one another, and consist of a garnetiferous amphibolite, composed chiefly of actinolite and garnet, with muscovite, some untwinned felspar and quartz. No intrusions of this rock have been found in the schists which represent the younger palæozoics, although both they and the Rupshu granite are often penetrated by dykes of the second or non-garnetiferous class; there is therefore no direct evidence of their age, but it seems probable that, were they post-carboniferous, they would be found intrusive in the beds of that system; it is of course possible that a more detailed examination of this very interesting area may prove that they occur among the sedimentary beds as well as in the gneiss.

Garnetiferous basic rocks.

The non-garnetiferous rocks consist chiefly of forms related to the augite-norites, and resemble the basic intrusives found in Spiti. In the present state of our knowledge of the petrography of Rupshu, detailed descriptions of isolated specimens would be of no particular utility, but it is perhaps as well to record the fact that they occur as dykes among the carboniferous and permian beds and in the Rupshu granite; they therefore constitute the youngest intrusive rocks of Southern Rupshu, and are probably related to the pyroxenites and other basic igneous rocks found further to the north, specimens of which have recently been described by General McMahon.[1]

Basic rocks without garnets.

[1] Memoirs, G. S. I., vol. XXXI, pp. 303—329.

CHAPTER VIII.

ECONOMIC GEOLOGY.

Even were the Spiti valley rich in useful minerals, its inaccessibility would be a fatal bar to profitable exploitation.

Gypsum.

As it is, however, the only mineral obtainable in any quantity is gypsum which, as already noted by Mr. Mallet,[1] occurs at Huling and Changrizang in lower Spiti. It is also found in the valley of the Gyundi river in upper Spiti and between the Lipak and Yulang rivers in Kanaur. In the last-named locality it occurs in immense masses and thick beds replacing the carboniferous limestone (Pl. XVI). It is massive, very pure and soft, and could be mined with ease, but the cost of transport to the nearest market would be so high as to preclude the possibility of its competing with the gypsum of the Salt Range or of other more accessible localities. It is at present employed locally to some extent as a whitewash for the outer walls of houses, "chhortens" and "dukdens" (Buddhist shrines), but does not appear to be put to any other uses.

Its origin has been discussed by Mr. Mallet in the paper already quoted. He attributes it to the action of the sulphurous thermal springs which are found near the gypsum; the water of these, carrying sulphuric acid in solution, would act on the carbonate of lime of the limestones, thereby forming gypsum. That this explanation is the true one is proved by the fact that Mr. Mallet found the action still going on at the time of his visit, while the masses of gypsum near the Lipak and Yulang rivers are found to pass horizontally into unaltered limestone, and to contain lumps and masses of that rock, thus showing that the change has taken place *in situ*. Analyses made by the present writer of the massive gypsum failed to show the presence of anhydrite.

[1] Memoirs, G. S. I., vol. V.

Iron.

Iron.

Red hæmatite is found in the high range about 3 miles south-west of Muth in the Pin valley. It forms a band about 3 feet thick among the cambrian trilobite beds, and boulders of it occur in the conglomerate which underlies the lower silurian quartzite. Its total extent is small, and, in the absence of fuel, it is of no economic value.

Galena.

Galena

Galena occurs in a small quartz vein, infiltrated along a fault plane in the upper triassic limestones in the hills between Po and Dankhar. It is found only in small, isolated cubes, which are laboriously extracted by the local *shikaris* for the manufacture of bullets.

Gold

Gold.

The only locality in which this mineral has been found in the area dealt with in the present Memoir is Chagya Sumdo, on the border between Rupshu and the Tibetan province of To-tzo. A few pits, from ten to fifteen feet in depth, are to be seen in the sub-recent gravels on the left bank of the Párá river. They were said to have been dug some fifteen or sixteen years previously by the Tibetans, who obtained a small quantity of gold, but eventually deserted them as not being sufficiently productive. A small amount of material was panned here, and at other localities in Rupshu, by the present writer, but no trace of gold was found.

Amethyst.

Amethyst.

Amethyst (amethystine quartz) is common in the Sutlej valley in Bashahr, and is known to occur at several localities. Both it and the blue kyanite, which is so plentiful in Kanaur and Bhabeh, and indeed throughout Bashahr State, have been repeatedly mistaken by natives and inexperienced Europeans for sapphire.

CHAPTER IX.

CORRELATION WITH THE SIMLA SERIES.

The correlation of the metamorphosed sedimentary beds of the lower Himálayas with beds of known age in the higher parts of that range has ever been one of the most difficult problems with which the Himalayan geologist is called upon to deal. The apparent absence of fossils in the pre-tertiary rocks of the lower ranges and the discontinuity in the beds caused by the numerous intrusions of great masses of granite, leave us dependent entirely on lithological characters as a means of correlating the rocks of different areas, and in the face of such extreme variations in character of the palæozoic systems as are displayed in the sections of comparatively adjacent areas, such as Spiti and Kanaur, this method of correlation can be employed only with the greatest discretion.

In the present chapter it is proposed to deal with those aspects of the question on which the recent survey of Spiti may have thrown a little more light, that is to say, the correlation of the various beds found at Simla, and in the Sutlej valley with their possible representatives among the higher ranges to the north.

It is only within comparatively recent years that the real difficulties of this problem seem to have been realised, the earliest observers having been content to apportion, somewhat dogmatically, the various Simla beds among the fossiliferous rocks of Spiti. Subsequently, however, the question was studied more deeply by General McMahon and Mr. Oldham, who made detailed surveys of Simla and neighbouring areas and also visited both Spiti and Kashmir. The observations are embodied in numerous papers published in the "Records" of this Department, and a summary of Mr. Oldham's conclusions will be found in the "Manual of the Geology of India."[1] Of the area in which these rocks and their representatives have been studied by Mr. Oldham, only two small portions have been visited by the present

[1] Manual, 2nd Edn., pp. 132—138.

writer, *viz.*, Spiti, and the immediate neighbourhood of Simla, and any observations which may appear to run counter to the generally accepted views are put forward with diffidence and chiefly with a view to drawing the attention of future workers to certain points which appear to have hitherto escaped notice and which may help eventually to elucidate this difficult problem.

The earliest attempt at correlation was made by Stoliczka, who identified the *infra*-Blaini beds (Simla slates) with the upper part of his Bhabeh series, *i.e.*, with the beds regarded in this Memoir as of middle and upper cambrian age.

The Blaini boulder slate he correlated with the lower part of his Muth series, the Blaini limestone with the "arenaceous limestone" of the same series, and the Boileauganj quartzite and schists with his "Kuling series"; while the Muth quartzite he believed to be represented by "a small thickness of a whitish quartzose schist" above the Blaini limestone.

Adopting Mr. Oldham's classification of the Simla beds as published in Records, vol. XX, we obtain the correlation shown in the following table :—

Simla (Oldham).	Spiti (Stoliczka).
Jutogh carbonaceous slates and limestone.	
Boileauganj quartzites and schists.	Kuling series (permian and carboniferous of present memoir).
Lower carbonaceous slates.	Muth quartzite (= ? devonian).
Blaini limestone.	Arenaceous limestone (= partly upper, partly lower silurian).
Upper boulder bed. Bleach slates. Lower boulder bed.	Lowest beds of Muth series (= lower silurian).
Infra-Blaini beds.	Upper Bhabeh series (= upper and middle cambrian).

This correlation was subsequently followed by Lydekker, who states that "there is no room for doubt as to the identity of the Panjál rocks with the Blaini and *infra*-Blaini series of [Simla] and the Muth and Bhabeh series of [Spiti]"[1]: he was thus led to attribute to his Panjál system an age very much greater than now appears probable.

So far as the area touched on in the present memoir is concerned, there is a very considerable superficial resemblance between the lower palæozoic rocks of Spiti and some of the Simla beds, certain units in the one finding their exact *lithological* counterparts in the other. Thus the quartzites, slates and grits of the *infra*-Blaini beds, as seen near the tunnel on the Simla-Mashobra road, are indistinguishable in hand specimens from the cambrian rocks of the Thanam valley in Bashahr and of the Parahio valley in Spiti. Higher in the cambrian system, both in Bashahr and Spiti, are soft, intensely black carbonaceous shales, which are the exact counterpart of the carbonaceous shales of Simla, while the reddish-brown and pink dolomite of the upper cambrian of the Parahio valley bears a strong lithological resemblance to the Blaini dolomite.

In the case of the lower silurian conglomerate, the resemblance is less striking. With regard to its correlation by Stoliczka with the Blaini boulder bed, Mr. Oldham has remarked: "The Muth series of Stoliczka resembles nothing I am acquainted with in the Simla area. One thing I feel certain of, that it does not represent the Blaini group of Simla. The conglomerates of Muth are perfectly ordinary conglomerates and quite different to the very peculiar Blaini rock." So far as the conglomerate is concerned, the outcrops near Muth undoubtedly bear out Mr. Oldham's view as to its origin. In many places, however, where the rock has undergone a certain amount of shearing, the matrix resembles a fine-grained slate, though it is not in reality so fine as that of the Blaini rock, and more nearly resembles that of the Po conglomerate (see below, p. 109; see also Pl. XVII). Certainly there is no reason to look upon it as of glacial origin. At the same

[1] Memoirs, G. S. I., vol. XXII, p. 249.

time, the series frequently bears a distinct superficial resemblance to the Blaini boulder-beds; in each area there are usually two boulder-beds, separated from one another by a band of slate, while near Shián in the Pin valley the lower bed is underlain by a narrow band of rock consisting of small pebbles and angular fragments of white quartz in a dark, slaty matrix, and strongly resembling a similar narrow band of conglomerate which is found at Simla at the base of the boulder-beds, and has been traced from the Elysium spur round the flank of Jakko to the Sanjauli bazar.

So much for mere lithological resemblance: when, however, we turn to the actual sequence, we find that there is considerable discordance between the two areas This will be readily seen by a glance at the following parallel arrangement of the beds :—

Simla.	Spiti.
Carbonaceous slate.	Conglomerate.
Dolomite.	Slate.
Boulder slate.	Conglomerate.
Bleach slate.	Dolomite and slate.
Boulder slate.	Carbonaceous slate.
Infra-Blaini slates, grits and quartzites.	Cambrian slate, grits and quartzites.

It will thus be seen that the order of the beds above the lithologically similar slates, grits and quartzites is in the one area exactly the reverse of that in the other. This cannot be explained in the present case by subsequent inversion of the strata in the Simla area: it is, however, possible to conceive of conditions under which deposition might take place simultaneously in some such reverse order in two areas not far removed from one another, but between the two, there would necessarily be found a gradation from the one series into the other. The beds between Spiti and Simla are so highly altered by dynamo- and contact-metamorphism that there is little hope of finding confirmation, or the reverse, and in view of the discrepancies between the two series, no attempt at correlation, on the strength of lithological resemblance of isolated members, could be justified. It has, however, been deemed advisable to draw attention to such points of similarity as exist.

With regard to the upper beds of the Simla series, *viz.*, the Boileauganj quartzite and the Jutogh limestone, there are so many similar combinations in Spiti—*e.g.*, lower silurian quartzite and silurian limestone, Muth quartzite and (?) devonian limestone, carboniferous quartzite of the Lipak river and carboniferous limestone—that any attempt at correlation is impossible.

Another suggested correlation, which, if subsequently found to be correct, would to some extent favour Stoliczka's original view, has been quite recently put forward by General McMahon, whose extensive acquaintance with the Blaini and *infra*-Blaini beds of the Himálayas entitles his opinion to no small weight. The correlation in question is that of a certain conglomerate, found by Major McMahon in Chitral, with the Blaini boulder-slate; a full description of the rock will be found in a recent number of the Geological Magazine[1]: unfortunately, General McMahon's observations were made only on hand specimens, which are so frequently misleading.

The conglomerate is said to occur below a bed of red sandstone which is in turn overlain by limestone containing devonian fossils.[2] It has already been stated,[3] that the sequence as recorded above distinctly recalls the conglomerate, red quartzite and limestone, *i.e.*, the silurian system, of Spiti, but in the absence of any details as to the thickness or subdivisions of the members of the Chitral beds, it is impossible to say how far the one series may represent the other, but even should the Chitral series and silurian of Spiti eventually be proved, on palæontological grounds, to be one and the same, the probability of being able to connect two such widely separated areas as Chitral and Simla seems very remote.

It is, however, interesting to note that in Hazara a somewhat similar series was found by Mr. Middlemiss who described[4] in some detail an "*infra*-trias" conglomerate which he has correlated with the Talchir

[1] Geol. Magazine, vol. IX, No. 1, January 1902, pp. 1—8.
[2] *Ibid.*, No. 2, February, 1902, pp. 49—58.
[3] *Supra*, p. 31.
[4] Memoirs, G. S. I., vol. XXVI, pp. 17—23.

boulder-bed of the Salt Range, the Blaini boulder-slate of Simla and the Panjál conglomerate of Kashmir, thus referring all four to the same horizon. Of these, Mr. Middlemiss has had the opportunity of examining all but the Panjál conglomerate, and his conclusions are therefore entitled to no small degree of consideration. On the other hand, it is difficult to resist the temptation to correlate the Hazara rock with the lower silurian conglomerate of Spiti, for each of these passes up into a comparatively thin band of shale, overlain by a red—at times purple—quartzite in the one case, and by a purple sandstone in the other.

The most recent and generally accepted views with regard to the correlation of the Spiti and Simla rocks are to be found in the "Manual of the Geology of India,"[1] in which the Blaini boulder-slate is indicated as the probable equivalent of the Panjál conglomerates of Kashmir and the Talchir boulder-bed of the Salt Range, and these again referred to the permian conglomerates of Po in Spiti. The first observer to draw attention to the Po rock was General McMahon, who described an outcrop of conglomerate, seen on the road between that village and Dankhar, as consisting of large boulders in a fine-grained, slaty matrix, the whole resembling the Blaini "conglomerate."[2] In a subsequent paper,[3] however, he appears to accept Stoliczka's correlation of the Blaini rock with the silurian conglomerate of Muth, thus following him in supposing that the cambrian and silurian rocks near that village were merely a different facies of the slates and quartzites of lower Spiti: there is now no doubt that the latter series represents the permian and part of the carboniferous systems, and this still further emphasises the futility of any attempt at correlation on the strength of mere lithological resemblance.

As has already been stated above (p. 52), the permian conglomerate of Spiti is also exposed at the junction of the Lingti and Spiti rivers below Dankhar. This outcrop was noticed both by General McMahon

[1] Manual, G. S. I., 2nd Ed., pp. 132—138.
[2] Records, G. S. I., vol. XII, p. 63.
[3] Records, G. S. I., vol. XIV, p. 309.

and Mr. Oldham, the latter of whom draws attention to the resemblance borne by the rock to the Blaini conglomeratic slate.[1]

During the recent survey of Spiti the present writer paid a considerable amount of attention to the question of the supposed resemblance of these permian conglomerates to the Blaini boulder-slates, and a detailed examination of the sections near Po and Pomarang, and also of the outcrops mentioned by McMahon and Oldham, has led him to the conclusion that the resemblance is only superficial. The Blaini boulder-slate is now generally regarded as of glacial origin, owing to the fact of its being composed of comparatively large boulders in a fine-grained, silty matrix, and the same characters have been claimed for the conglomerate seen near Po and Dankhar. This latter rock occurs among a series of typical shallow-water deposits, consisting of quartzites, grits, gritty slates, conglomerates and occasional beds of fine-grained slate. The matrix of the conglomerate varies from a coarse grit to a gritty slate, corresponding in composition to a fine-grained, somewhat argillaceous sandstone: the rock has usually undergone a considerable amount of crushing and shearing, thus being converted into a boulder-bearing slate, the included fragments varying in size from small pebbles to boulders nearly a foot in diameter; the latter, however, are rare, the pebbles being as a rule about the size of the fist.

Under the microscope, the rock appears to be an ordinary conglomerate; figs. 1 and 2 on Plate XVII represent sections of the matrix collected from the localities mentioned by Mr. Oldham and General McMahon. It will be seen that the specimen from Po is quite coarse and gritty, while that from below Dankhar is finer, but still only a gritty, arenaceous slate; this represents the finest-grained matrix that the present writer has been able to find among the conglomerates of Spiti. In addition to the conglomerate, beds of fine-grained slate, presumably representing true silts, are not uncommon in the series, but have never been found to contain pebbles or boulders, though

[1] Records, G. S. I., vol. XXI, p. 151.

frequently full of large concretions, and no pebble or boulder-bearing bed has been found with a silty matrix. There is therefore no evidence in support of the theory of a glacial origin for the conglomerates, which, with the slates, grits and quartzites with which they are associated, are just such rocks as might be expected to occur among a series of shallow-water deposits laid down in estuaries or in the neighbourhood of a shore-line.

Figure 3, Plate XVII, represents the matrix of the Blaini boulder-slate as seen on the Mall at Simla, near Sanjauli bazar. It will be seen that it is very much finer than the matrix of the Spiti conglomerate, while the present writer has found that larger boulders occur in the Simla rock than are to be seen in its supposed representatives in Spiti.

It would seem, therefore, that correlation of the two series on the ground of a common glacial origin is not warranted, but this cannot be regarded as sufficient reason for denying that such correlation may still be correct.

Certain other points of resemblance were found by Mr. Oldham between the Blaini rocks and the permian beds of Spiti; one of these was the occurrence of carbonaceous shales above the boulder-bearing beds in both areas. The carbonaceous shales of Simla require little description: they are soft, densely black and graphitic, their appearance having frequently led to their being mistaken, by those not versed in such matters, for coal. On the other hand, their supposed representatives in Spiti, which have been described in this memoir as the "Productus shales," though certainly black at times, are more usually dark-brown, gritty and micaceous, with a few indistinct plant impressions in the lower beds. They have not, however, even where greatly metamorphosed, as in Rupshu, that intensely black, coaly and graphitic appearance so characteristic of the Simla carbonaceous shales, which are much more nearly related, lithologically, to the cambrian carbonaceous shales of Bashahr.

A further argument adduced by Mr. Oldham in favour of his correlation was the common resemblance of the Po conglomerate and the Blaini boulder-slate to the Panjál conglomerates of Kashmir and

to the Talchir boulder-bed of the Salt Range. The present writer has not had the opportunity of seeing either of the two last-named formations, but the recent survey of Spiti may nevertheless throw some light on the question, for it is hoped that a detailed examination of the fossils collected from the Po series may definitely fix the age of the conglomerates; at present it is only possible to say that they are either upper carboniferous or permian, but their exact horizon is still a matter of doubt. Quite recently a series of slates and limestones have been found by Dr. Noetling in Kashmir; they are said to overlie tuffs, which are not improbably the representatives of Lydekker's "Panjál system," and are said to contain permian fishes and lower Gondwana plants, in which case the underlying beds would appear to be referable to the beds at the base of the Gondwanas, or, in other words, to the Talchir boulder-bed, and should the tuff series be found to contain the Panjál conglomerate, correlation with the Salt Range might safely be considered as established. As stated above (p. 57), it is highly probable that the Po series of shales and quartzites, as well as the overlying permian beds, will be found to be continuous, from upper Spiti, at least into the Lingti valley in Kashmir, and a survey of the intervening area should, therefore, definitely determine the relation between Lydekker's "Panjál system" and the neighbouring beds of Spiti; and such a correlation, once established, would probably link up the Salt Range with both Spiti and Kashmir. This, however, would not necessarily bring us much nearer to the solution of the problem of the age of the Blaini rocks, for we have seen that there are two series in Spiti, differing widely from one another in age, each of which has certain points of lithological resemblance to the Simla beds, but in neither case do there appear to be sufficient grounds for definite correlation, and until evidence of a more satisfactory nature can be obtained, we must look upon the question as still unsolved.

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GEOGRAPHICAL INDEX.

APPENDIX.

Bibliography.

An extensive bibliography of Himalayan literature published before the year 1891, has been given by Mr. Griesbach in his memoir on the Geology of the Central Himálayas (Memoirs of the Geological Survey of India, XXIII, pages 3—9), and a further list of works dealing with the North-West Himálayas and neighbouring areas will be found in Mr. Lydekker's "Geology of Kashmir" (Memoirs of the Geological Survey of India, XXII). Since the appearance of those Memoirs, a considerable amount of literature has been published on the subject of the palæontology and stratigraphical geology of the Himálayas, and since this has a more or less direct bearing on the subject of the present memoir, it has been included in the following list of papers relating to Spiti and adjacent areas:—

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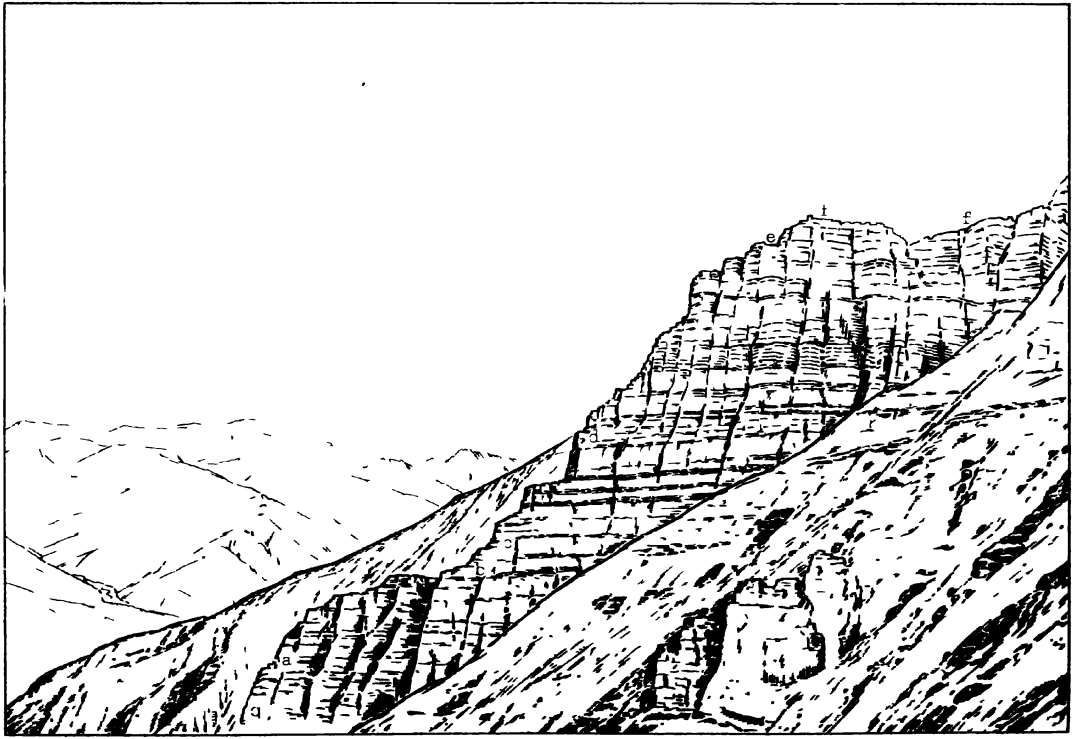
LIST OF PLATES.

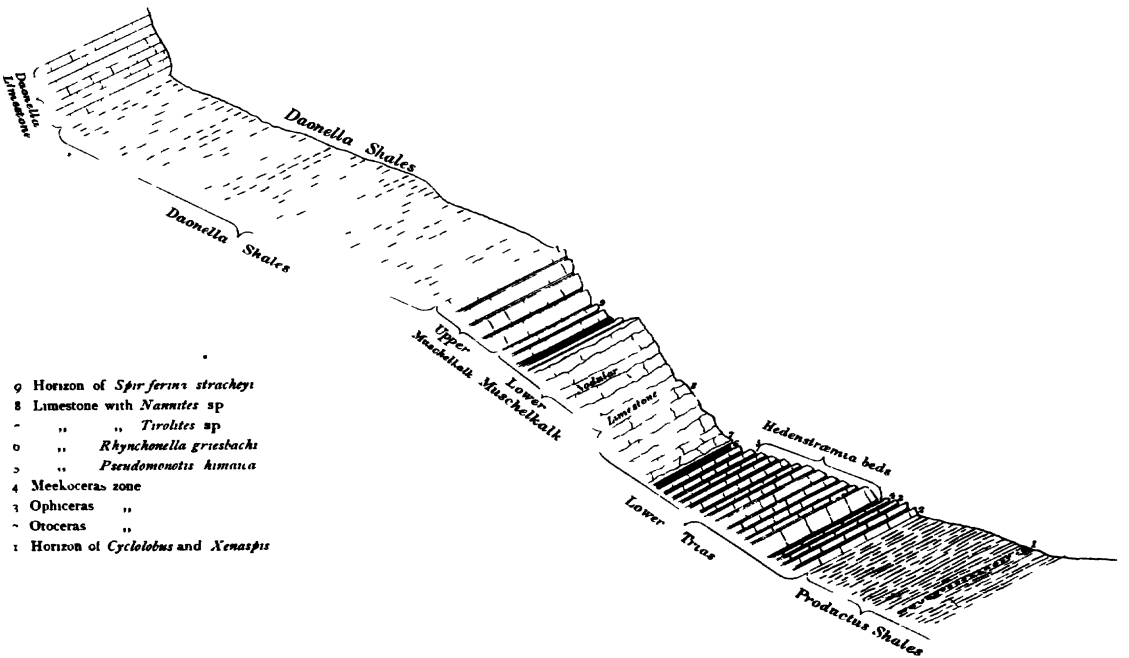
PLATE 2.

a to *f*. Fossiliferous shales and limestones. (See pages 37 to 41.)

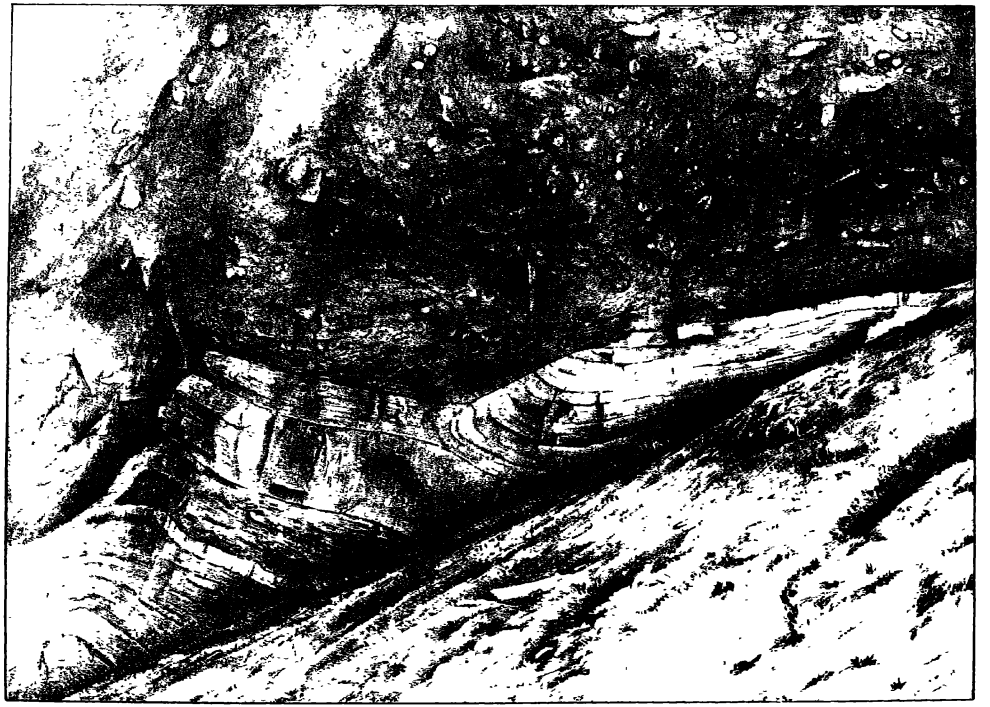
q. Unfossiliferous white quartzite.



CARBONIFEROUS BEDS ON LEFT SIDE OF LIPAK R., BELOW TANGA E. G.



Lower and Middle Trias in hills S. E. of Muth.



From a Photograph by H H. Hayden.

UNCONFORMITY IN UPPER CAMBRIAN BEDS, RIGHT SIDE OF PARAHIO RIVER

PLATE 7

4. Lower silurian conglomerate (No. 19, p 14).
3. Upper cambrian shale and quartzite (No. 18, p. 14).
2. „ „ upper dolomite (No. 17, p. 14).
1. „ „ lower „ (No. 15, p. 14).

H. H. Hayden, del.

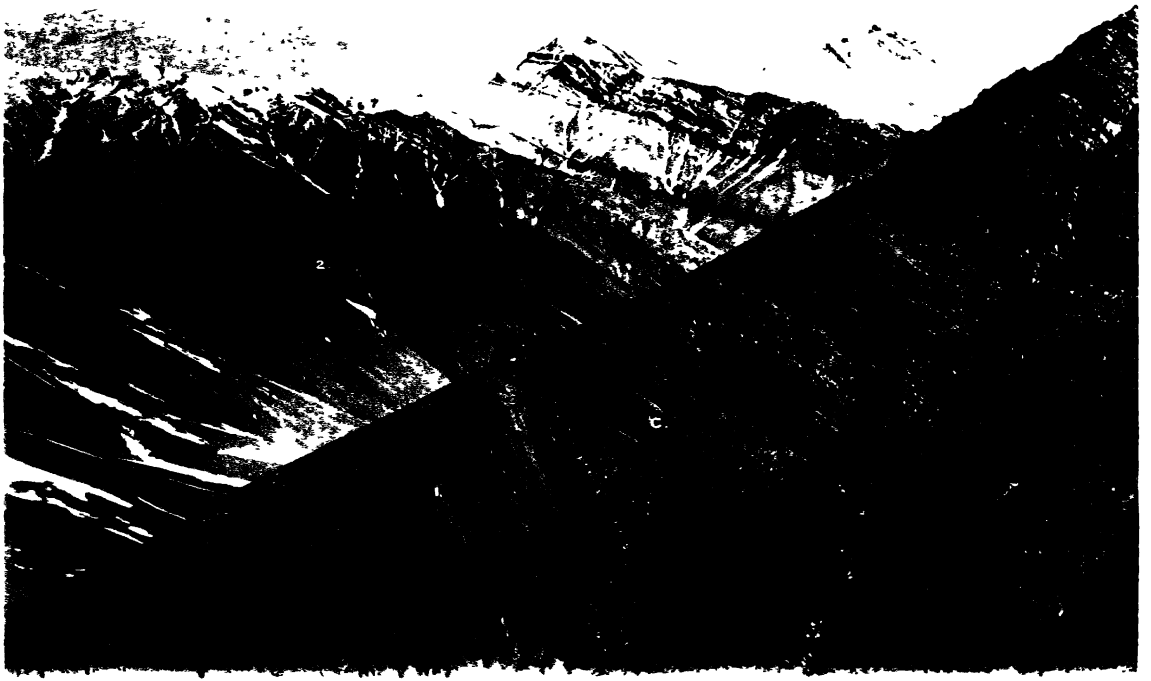
JUNCTION OF CAMBRIAN AND SILURIAN BEDS IN HILLS ON LEFT SIDE OF PARAHIO RIVER.

PLATE 8.

10. Tropites beds.
9. Grey beds.
8. Daonella limestone.
7. Daonella shale.
6. Muschelkalk and lower trias.
5. Productus shales.
4. Muth quartzite.
3. Silurian limestone.
2. Red lower silurian quartzite.
c. Lower silurian conglomerate.
1. Cambrian slates and quartzite.

1. and c are separated from one another by a fault (see p 23).

F. H. Hayden. Memoirs Vol. XXXVI. Pl. 1, Pl. 8

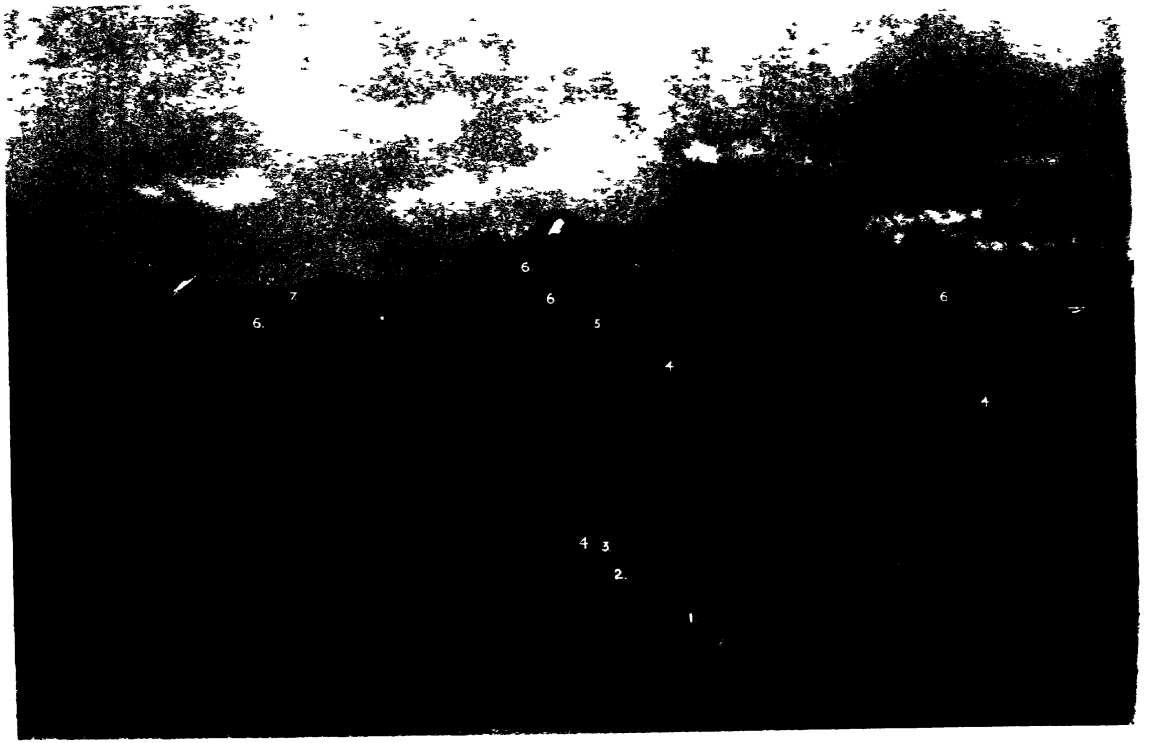


H. H. Hayden Phot.

PALÆOZOIC AND MESOZOIC BEDS BEHIND MUTH

PLATE 9.

7. Productus shales.
6. Muth quartzite.
5. Silurian limestone.
4. Lower silurian quartzite.
3. „ „ conglomerate.
2. Cambrian dolomite.
1. „ slates and quartzites.



PALÆOZOIC BEDS IN HILLS BETWEEN PARAHIO AND PIN RIVERS

PLATE 10.

6. Daonella shales.
5. Muschelkalk.
4. Lower trias.
3. Productus shales.
2. Muth quartzite.
1. Siluriar limestone.

MUTH QUARTZITE AT HEAD OF TETI RIVER BASHAHR

PLATE II.

8. Daonella limestone.
7. Daonella shales.
6. Muschelkalk.
5. Lower trias.
4. Productus shales.
3. Muth quartzite.
2. Silurian limestone.
1. Lower silurian quartzite.

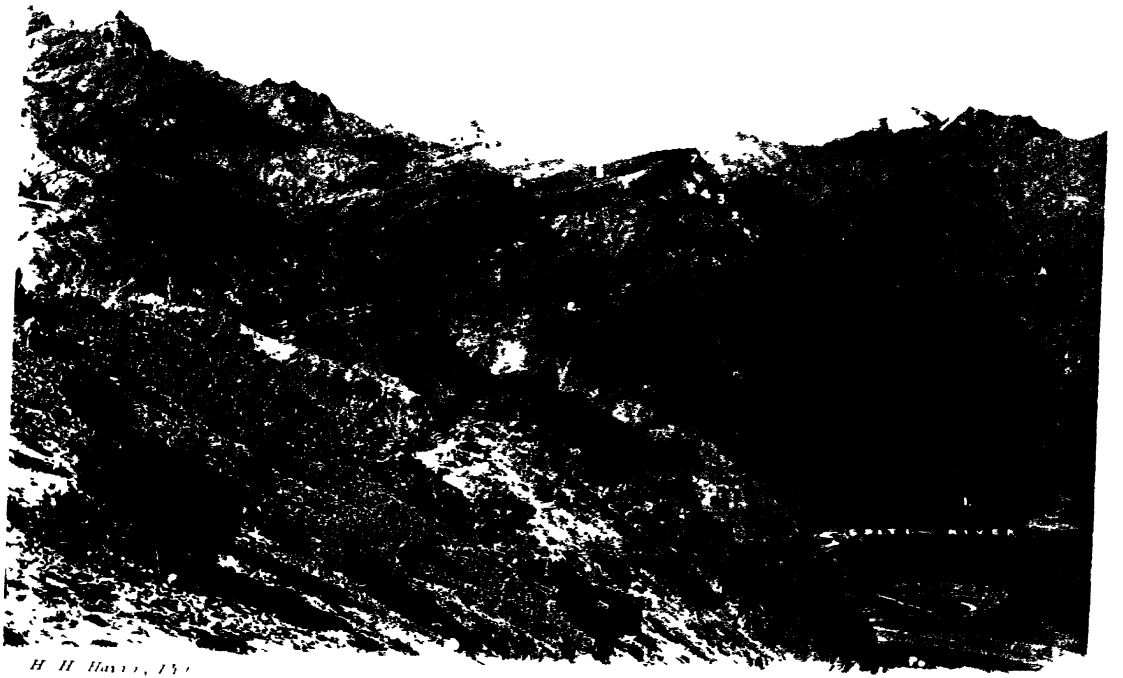
In the higher ridges the Muth quartzite had been completely removed before the deposition of the Productus shales.

H. H. Hayden del.

JUNCTION OF PALÆOZOIC AND MESOZOIC BEDS, UPPER THANAM VALLEY, BASHAHR.

PLATE 12.

8 Grey beds.
7. Daonella limestone.
6. Daonella shales.
5. Muschelkalk.
4. Productus shales.
3. Lower permian conglomerate.
2. Upper carboniferous quartzite and shale.
1. Fenestella shales.



H. H. Hayden, del.

CARBONIFEROUS AND TRIAS ON LEFT SIDE OF SPITI RIVER, BETWEEN PO AND THABO

PLATE 13

3. Monotis beds.
2. Coral limestone.
1. Juvavites beds.

FOLDED UPPER TRIAS NORTH SIDE OF MÁNIRANG PASS

PLATE 14.

T. Upper Trias.

UPPER SPITI RIVER, BETWEEN KI AND KIOTO

FIG. 1. MEGALODON LIMESTONE.

FIG. 2. GRANITE VEINS IN CAMBRIAN SLATES, ABOVE NAKU, KANAUR.

H. H. Hayden

MASSES OF GYPSUM IN CARBONIFEROUS LIMESTONES UPPER YULANG RIVER KANAUR

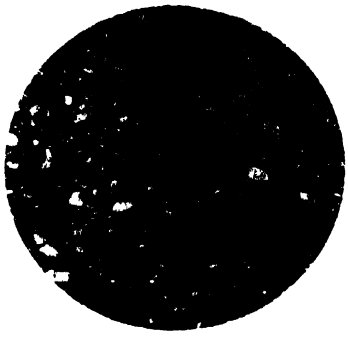


FIG 1 MATRIX OF PERMIAN CONGLOMERATE, NEAR PO

FIG 2 MATRIX OF PERMIAN CONGLOMERATE, NEAR DANKHAR.

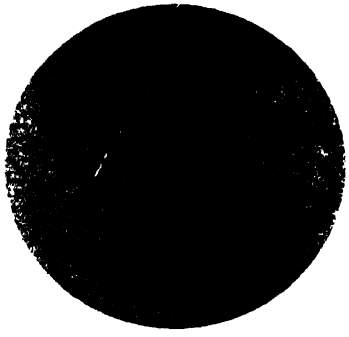


FIG. 3. MATRIX OF BLAINI BOULDER-SLATE.

Part 3.—Note on the progress of the gold industry in Wynaad, Nilgiri district. Notes on the representatives of the Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—On the geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Further notices of Siwalik mammalia. Notes on some Siwalik birds. Notes of a tour through Hangrang and Spiti. On a recent mud eruption in Ramri Island (Arakan). On Beaunite, with Rhodonite, from near Nagpur, Central Provinces. Palæontological notes from the Satpura coal-basin. Statistics of coal importations into India.

Part 2.—On the Mohpani coal-field. On Pyrolusite with Psilomelane occurring at Gosalpur, Jabalpur district. A geological reconnaissance from the Indus at Kushalgarh to the Kurram at Thal on the Afghan frontier. Further notes on the geology of the Upper Punjab.

Part 3.—On the geological features of the northern part of Madura district, the Pudukota State, and the southern parts of the Tanjore and Trichinopoly districts included within the limits of sheet 80 of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1877-78. Notes on the genus Sphenophyllum and other Equisetaceæ, with reference to the Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). On Mysorin and Atacamite from the Nellore district. On corundum from the Khasi Hills. On the Joga neighbourhood and old mines on the Nerbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjab. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in the neighbourhood of Sironcha. Geology of Ladak and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Teeth of fossil fishes from Ramri Island and the Punjab. Note on the fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Shekh Budin, and Sirgujah. On volcanic foci of eruption in the Konkan.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicherry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kumaun lakes. On the discovery of a celt of palæolithic type in the Punjab, Palæontological notes from the Karharbari and South Rewah coal-fields. Further notes on the correlation of the Gondwana flora with other floras. Additional note on the artesian wells at Pondicherry. Salt in Rajputana. Record of gas and mud eruptions on the Arakan coast on 12th March 1879 and in June 1843.

Part 4.—On some pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Arvali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The re-soils of Upper India. Note on the Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts, being fifth notice of the geology of Kashmir and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the ferruginous beds associated with the basaltic rocks of north-eastern Ulster, in relation to Indian laterite. On some Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on the lower trias of the Himalayas.' On some mammalian fossils from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society.

Part 2.—The Nahan-Siwalik unconformity in the North-western Himalaya. On some Gondwana vertebrates. On the ossiferous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain; and the Coal and Metalliferous Mines Acts of 1872 (England). On cobaltite and danaite from the Khetri mines, Rajputana; with some remarks on Jaipurite (Syepoorite). On the occurrence of zinc ore (Smithsonite and Blende) with barytes, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

Part 3.—Artesian borings in India. On oligoclase granite at Wangtu on the Sutlej, North-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collection of the British Museum.

Part 4.—Remarks on the unification of geological nomenclature and cartography. On the geology of the Arvali region, central and eastern. On a specimen of native antimony obtained at Pulo Obin, near Singapore. On Turgite from the neighbourhood of Juggiapett, Kistnah district, and on zinc carbonate from Karnul, Madras. Note on the section from Dalhousie to Pangi, *vid* the Sach Pass. On the South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1.—Annual report for 1881. Geology of North-west Kashmir and Khagan (being sixth notice of geology of Kashmir and neighbouring territories). On some Gondwana labyrinthodonts. On some Siwalik and Jamna mammals. The geology of Dalhousie, North-west Himalaya. On remains of palm leaves from the (tertiary) Murree and Kasauli beds in India. On Iridosmine from the Noa-Dibing river, Upper Assam, and on Platinum from Chutia Nagpur. On (1) a copper mine lately opened near Yoagri hill, in the Darjiling district; (2) arsenical pyrites in the same neighbourhood; (3) kaolin at Darjiling (being 3rd appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal-field, Upper Assam. Experiments on the coal of Pind Dadun Khan, Salt-range, with reference to the production of gas, made April 29th, 1881. Report on the proceedings and result of the International Geological Congress of Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkilli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the Coal-bearing rocks of the valleys of the Upper Rer and the Mand rivers in Western Chutia Nagpur. On the Pench river coal-field in Chhindwara district, Central Provinces. On borings for coal at Engsein, British Burma. On sapphires recently discovered in the North-west Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

Part 3.—Note on the coal of Mach (Much) in the Bolan Pass, and of Sharag or Sharigh on the Harnai route between Sibi and Quetta. New faces observed on crystals of stilbite from the Western Ghâts, Bombay. On the traps of Darang and Mandi in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

Part 4.—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Bijori Labyrinthodont. On a skull of Hippotherium antilopinum. On the iron ores, and subsidiary materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gosulpore, Jabalpur district. Further notes on the Umaria coal-field.

Part 3.—On the microscopic structure of some Dalhousie rocks. On the lavas of Aden. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Mastodon angustidens in India. On a traverse between Almora and Mussooree made in October 1882. On the cretaceous coal-measures at Borsora, in the Khasia Hills, near Laour, in Sylhet.

Part 4.—Palæontological notes from the Daltonganj and Hutar coal-fields in Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cachar Hills. On native lead from Maulmain and chromite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice.—Irrigation from wells in the North-Western Provinces and Oudh.

Vol. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks of Narrakal and Alleppy on the Travancore coast. Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Chuari and Sihunta parganas of Chamba. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kashmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Choi coal exploration. On the re-discovery of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and the Laramie group in western North America.

Part 3.—On the miscroscopic structure of some Arvali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarh-Hingir coal-field (first notice). Note on lignite near Raipore, Central Provinces. The Turquoise mines of Nishâpûr, Khorassan. Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, south-west Khasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On the Geology of part of the Gangasulan pargana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-west Himalayas. On the geology of the Takht-i-Suleiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Work at the Billa Surgam caves.

Vol. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of the country between the Singareni coal-field and Hyderabad. On coal and limestone in the Doigrung river, near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2.—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Mandhali series in the Lower Himalaya. On a second species of Siwalik camel (Camelus Antiquus, nobis ex Fale. and Caut. MS.). On the Geology of Chamba. On the probability of obtaining water by means of artesian wells in the plains of Upper India. Further considerations upon artesian sources in the plains of Upper India. On the geology of the Aka Hills. On the alleged tendency of the Arakan mud volcanoes to burst into eruption most frequently during the rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3.—On the Geology of the Andaman Islands. On a third species of Merycopotamus. Some observations on percolation as affected by current. Notice of the Pirthalla and Chandpur meteorites. Report on the oil-wells and coal in the Thayetmyo district, British Burma. On some antimony deposits in the Maulmain district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

Part 4.—Geological work in the Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th 1885. On the Kashmir earthquake of 30th May 1885. On the results of Mr. H. B. Foote's further excavations in the Billa Surgam caves. On the mineral hitherto known as Nepaulite. Notice of the Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1.—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic Fossils recently collected by Dr. H. Warth, in the Olive group of the Salt-range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian Field notes. On the section from Simla to Wangtu, and on the petrological character of the Amphibolites and Quartz Diorites of the Sutlej valley.

Part 2.—On the Geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in the Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

Part 3.—Geological sketch of the Vizagapatam district, Madras. Preliminary note on the geology of Northern Jesalmer. On the microscopic structure of some specimens of the Malani rocks of the Arvali region. On the Malanjkhandi copper-ore in the Balaghat district, C. P.

Part 4.—On the occurrence of petroleum in India. On the petroleum exploration at Khátan. Boring exploration in the Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice of the Nammianthal aerolite. Analysis of gold dust from the Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1.—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traverse through Jaunsar-Bawar and Tiri-Garhwal. On the geology of the Garo Hills. On some Indian image-stones. On soundings recently taken off Barren Island and Narcondam. On a character of the Talchir boulder-beds. Analysis of Phosphatic Nodules from the Salt-range, Punjab.

Part 2.—The fossil vertebrata of India. On the Echinoidea of the cretaceous series of the Lower Narbada Valley, with remarks upon their geological age. Field-notes: No. 5—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Deccan traps. On the Dolerite of the Chor. On the identity of the Olive series in the east with the speckled sandstone in the west of the Salt-range in the Punjab.

Part 3.—The retirement of Mr. Medlicott. Notice of J. B Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section I. Preliminary sketch of the geology of Simla and Jutogh. Note on the 'Lalitpur' meteorite.

Part 4.—Note on some points in Himalayan geology. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section II. The iron industry of the western portion of the District of Raipur. Notes on Upper Burma. Boring exploration in the Chhattisgarh coal-fields. (Second notice.) Some remarks on Pressure Metamorphism, with reference to the foliation of the Himalayan Gneissose Granite. A list and index of papers on Himalayan Geology and Microscopic Petrology, published in the preceding volumes of the records of the Geological Survey of India.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun Section III. The Birds'-nest or Elephant Island, Mergui Archipelago. Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A facetted pebble from the boulder bed ('speckled sandstone') of Mount Chel in the Salt-range in the Punjab. Examination of nodular stones obtained by trawling off Colombo.

Part 2.—Award of the Wollaston Gold Medal, Geological Society of London, 1888. The Dharwar System, the chief auriferous rock series in South India. On the Igneous rocks of the districts of Raipur and Balaghat, Central Provinces. On the Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3.—The Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' The sequence and correlation of the pre-tertiary sedimentary formations of the Simla region of the Lower Himalayas.

Part 4.—On Indian fossil vertebrates. On the geology of the North-west Himalayas. On blown-sand rock sculpture. Re-discovery of Nummulites in Zanskar. On some mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1.—Annual report for 1888. The Dharwar System, the chief auriferous rock-series in South India. (Second notice.) On the Wajra Karur diamonds, and on M. Chaper's alleged discovery of diamonds in pegmatite near that place. On the generic position of the so-called Plesiosaurus Indicus. On flexible sandstone or Itacolumite, with special reference to its nature and mode of occurrence in India, and the cause of its flexibility. On Siwalik and Narbada Chelonia.

Part 2.—Note on Indian Steatite. Distorted pebbles in the Siwalik conglomerate. 'The Carboniferous Glacial Period.' Notes on Dr. W. Waagen's 'Carboniferous Glacial Period.' On the oil-fields of Twingoung and Beme, Burma. The gypsum of the Nehal Nadi, Kumaun. On some of the materials for pottery obtainable in the neighbourhood of Jabalpur and of Umaria.

Part 3.—Abstract report on the coal outcrops in the Sharigh Valley, Baluchistan. On the discovery of Trilobites by Dr. H. Warth in the Neobolus beds of the Salt-range. Geological notes. On the Cherra Poonjee coal-field, in the Khasia Hills. On a Cobaltiferous Matt from Nepál. The President of the Geological Society of London on the International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4.—On the land-tortoises of the Siwaliks. On the pelvis of a ruminant from the Siwaliks. Recent assays from the Sambhar Salt-Lake in Rajputana. The Manganiferous Iron and Manganese Ores of Jabalpur. On some Palagonite-bearing raps of the Rájmahál hills and Deccan. On tin-smelting in the Malay Peninsula. Provisional index of the local distribution of important minerals, miscellaneous minerals, gemstones, and quarry stones in the Indian Empire. Part 1.

Vol. XXIII, 1890.

Part 1.—Annual report for 1889. On the Lakadong coal-fields, Jaintia Hills. On the Pectoral and pelvic girdles and skull of the Indian Dicynodonts. On certain vertebrate remains from the Nagpur district (with description of a fish-skull). Crystalline and metamorphic rocks of the Lower Himalayas, Garhwál and Kumaun, Section IV. On the bivalves of the Olive-group, Salt-range. On the mud-banks of the Travancore coast.

Part 2.—On the most favourable sites for Petroleum explorations in the Harnai district, Baluchistan. The Sapphire Mines of Kashmir. The supposed Matrix of the Diamond at Wajra Karur, Madras. The Sonapet Gold-field. Field Notes from the Shan Hills, (Upper Burma). A description of some new species of Syringosphæridæ, with remarks upon their structures, &c.

Part 3.—On the Geology and Economic Resources of the Country adjoining the Sind-Pishin Railway between Sharigh and Spintangi, and of the country between it and Khattan (with a map). Report of a Journey through India in the winter of 1888-89, by Dr. Johannes Walther, translated from the German, by R. Bruce Foote. On the Coal-fields of Lairungao, Maosandram, and Mao-be-lar-kar, in the Khasi Hills (with 3 plans). Further Note on Indian Steatite. Provisional Index of the Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in the Indian Empire (continued from p. 286, Vol. XXII).

Part 4.—Geological sketch of Naini Tal; with some remarks on the natural conditions governing mountain slopes (with a map and plate). Notes on some Fossil Indian Bird Bones. The Darjiling Coal between the Lisu and the Ramthi rivers, explored during season 1890-91 (with a map). The Basic Eruptive Rocks of the Kadapah Area. The Deep Boring at Lucknow. Preliminary Note on the Coal Seam of the Dore Ravine, Hazara (with two plates).

Vol. XXIV, 1891.

Part 1.—Annual report for 1890. On the Geology of the Salt-range of the Punjab, with a re-considered theory of the Origin and Age of the Salt-Marl (with five plates). On veins of Graphite in decomposed Gneiss (Laterite) in Ceylon. Extracts from the Journal of a trip to the Glaciers of the Kabru, Pandim, &c. The Salts of the Sambhar Lake in Rajputana, and of the Saline efflorescence called 'Reh' from Aligarh in the North-Western Provinces. Analysis of Dolomite from the Salt-range, Punjab.

Part 2.—Preliminary Report on the Oil locality near Moghal Kot, in the Sherani country, Suleiman Hills. On Mineral Oil from the Suleiman Hills. Note on the Geology of

the Lushai Hills. Report on the Coal-fields in the Northern Shan States. Note on the reported Namsèka Ruby-mine in the Mainglôn State. Note on the Tourmaline (Schorle)-Mines in the Mainglôn State. Note on a Salt-spring near Bawgyo, Thibaw State.

Part 3.—Boring Exploration *in the* Daltongunj Coal-field, *Palamow* (with a map). *Death of* DR. P. MARTIN DUNCAN. Contributions *to the* study *of the* Pyroxenic varieties *of* Gneiss *and of the* Scapolite-bearing Rocks.

Part 4.—On a Collection of Mammalian Bones from Mongolia. Further note on the Darjiling Coal Exploration. Notes on the Geology and Mineral Resources of Sikkim (with a map). Chemical and Physical notes on rocks from the Salt-range, Punjab (with two plates).

VOL. XXV, 1892.

Part 1.—Annual report for 1891. Report *on the* Geology *of* Thal Chotiáli *and part of the* Mari country (with a map and 5 plates). Petrological Notes *on the* Boulder-bed *of the* Salt-range, Punjáb, Sub-recent *and* Recent Deposits *of the valley plains of* Quetta, Pishin, and the Dasht-i-Bedaolat; *with appendices on the* Chamans *of* Quetta; *and the* Artesian water-supply *of* Quetta *and* Pishin (with one plate).

Part 2.—Geology *of the* Saféd Kóh (with 2 plates of sections). Report *on a* Survey *of the* Jherria Coal-field (with a map and 3 section plates) (*out of print*).

Part 3.—*Note on the* Locality *of* Indian Tscheffkinite. Geological Sketch *of the* country north of Bhamo. Preliminary Report *on the* economic resources *of the* Amber *and* Jade mines area *in* Upper Burma. Preliminary Report *on the* Iron-Ores *and* Iron-Industries *of the* Salem District. *On the* Occurrence *of* Riebeckite *in* India. Coal *on the* Great Tenasserim River, Mergui District, Lower Burma.

Part 4.—Report *on the* Oil Springs *at* Moghal Kot *in the* Shirani Hills (with 2 plates). Second Note *on* Mineral Oil *from the* Suleiman Hills. *On a* New Fossil, Amber-like Resin *occurring in* Burma. Preliminary notice *on the* Triassic Deposits *of the* Salt-range.

VOL. XXVI, 1893.

Part 1.—Annual report for 1892. Notes *on the* Central Himalayas (with map and plate). Note *on the occurrence of* Jadeite *in* Upper Burma (with a map). On *the* occurrence *of* Burmite, *a new* Fossil Resin *from* Upper Burma. Report *on the* Prospecting Operations, Mergui District, 1891-92.

Part 2.—Notes *on the* earthquake *in* Baluchistán *on the* 20th December 1892 (with 2 plates). Further Note *on* Burmite, *a new amber-like fossil resin from* Upper Burma. Note *on the* Alluvial deposits *and* Subterranean water-supply *of* Rangoon (with a map)

Part 3.—On the Geology *of the* Sherani Hills (with maps and plates). On Carboniferous Fossils *from* Tenasserim (with 1 plate). *On* a deep Boring *at* Chandernagore. Note *on* Granite *in the districts of* Tavoy *and* Mergui (with a plate).

Part 4.—*On the* Geology *of the country between the* Chappar Rift *and* Harnai *in* Baluchistán (with map and 3 plates). Notes *on the* Geology *of a part of the* Tenasserim Valley *with special reference to the* Tendau-Kamapying Coal-field (with two maps). *On a* Magnetite *from the* Madras Presidency containing Manganese *and* Alumina. *On* Hislopite (Haughton) (with a plate).

VOL. XXVII, 1894.

Part 1.—Annual report for 1893. Report *on the* Bhaganwala Coal-field, Salt-range, Punjab (with map and 2 plates).

Part 2.—Note *on the* Chemical qualities of petroleum *from* Burma. Note *on the* Singareni Coal-field, Hyderabad (Deccan) (with map and 3 plates of sections). Report *on the* Gohna Landslip, Garhwal (with 5 plates and 2 maps).

Part 3.—*On the* Cambrian Formation *of the* Eastern Salt-range (with a plate). The Giridih (Karharbari) Coal-field, *with notes on the* labour and methods of working (with 2 maps and 8 plates of sections). *On the* Occurrence of Chipped (?) Flints *in the* Upper Miocene of Burma (with a plate). Note *on the* Occurrence *of* Velates Schmideliana, Chemn., *and* Provelates grandis, Sow. *Sp. in the* Tertiary Formation *of* India *and* Burma (with 2 plates).

Part 4.—*Note on the* Geology of Wuntho *in* Upper Burma (with a map). Preliminary notice *on the* Echinoids *from the* Upper Cretaceous System of Baluchistán. *On* Highly Phosphatic Mica-Peridotites intrusive *in the* Lower Gondwana Rocks *of* Bengal. On a Mica-Hypersthene-Hornblende-Peridotite *in Bengal.*